National Research Corporation

Contract Research Division
NATIONAL RESEARCH CORPORATION
70 Memorial Drive
Cambridge 42, Massachusetts

RE-ORDER NO. 63-294

July 12, 1963

FINAL REPORT ON THE DETERMINATION OF THE EFFECT OF VACUUM EXPOSURE ON THE OPERATING CHARACTERISTICS OF TWO JET VANE ACTUATORS

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

by

Rosario P. Giammanco
Earl E. Chadsey, Jr.

Submitted to:

Jet Propulsion Laboratory
4300 Oak Grove Drive
Pasadena, California

Attn: Mr. Gerald S. Perkins,
Engineering Specialist, Sect. 344

Approved by:

Norman Beecher, Assistant
Director of Research

NRC Project No. 83-4-0101
NRC Quotation No. QSL-87

1 - 129

TABLE OF CONTENTS

2.

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

5

1.0 OBJECTIVES OF THE JET VANE ACTUATOR TESTS

1.1 To determine the operating characteristics of each actuator under the following conditions:

1.1.1 Atmospheric pressure prior to vacuum exposure.

1.1.2 Ultrahigh vacuum after an 8-day exposure to a pressure less than 1.0×10^{-8} torr.

1.1.3 Atmospheric pressure following vacuum exposure.

1.2 To determine the effects of the vacuum exposure on the working components and materials of the actuators under operating conditions.

1.3 To determine the effects of the vacuum exposure on static bearings and potentiometers of the type used in the actuator assembly.

1.4 To recommend changes in actuator design.

2.0 TEST RESULTS

2.1 Vacuum Exposure Test No. 1

2.1.1 Introduction

Exposure Test No. 1 was performed on Aeroflex Jet Vane Actuator, Serial No. 01, modified as described in Section 4.3 of this report; Markite Potentiometer, Serial No. 100; and Barden Bearing, No. SFR3BSSX112K5. Test operations were performed and test parameters were measured before, during, and after vacuum exposure to discover and determine any change in performance characteristics.

2.1.2 Installation of Test Pieces and Checkout of Assembly

On March 8, 1963, at 1200 hours the installation and checkout sequence for Exposure Test No. 1 were started. The jet vane actuator was mounted on the vacuum chamber cover and wired to the vacuum side of the electrical feedthrough. The power supply and instrumentation were assembled and checked out. The static potentiometer was wired to the vacuum side of the electrical feedthrough after having been conditioned as described in Section 10.1.2 of this report. The static Barden bearing was mounted on a vertical shaft and preloaded with a brass fly wheel. Figs. 1, 2 and 3 show the apparatus, the instrumentation and the mounted test specimens.

2.1.3 Atmospheric Pressure Operation

On March 15, 1963, at 2000 hours all circuits had been checked out and found to be operating properly. The jet vane actuator torque motor was then calibrated. The values obtained are shown in

Table 7. The multichannel recorder was then calibrated as described in Section 8.2.

On March 15, 1963, at 2330 hours the atmospheric pressure operation of the jet vane actuator was started. Duration of the operating period was 12 minutes and all test parameters were monitored. Data for the atmospheric pressure operation are shown in Table 1. During the operating period the recorded signals from the telemetry potentiometer and the torque motor indicated noise of varying amplitude and 100 cycle frequency. This data was telephoned to Mr. Gerry Perkins of JPL who stated that, "100 cycle noise was present during previous testing of the actuator unit." Attempts to eliminate the noise led to the conclusion that it was a characteristic of the circuitry. The operating sequence was then resumed. Resistance and voltage readings were taken on the static potentiometer as per Section 9.3. The preloaded bearing was checked as per Section 9.2 and the starting torque was found to be negligible. The vacuum system was then closed for pumping.

2.1.4 Pumpdown and Bakeout

On March 16, 1963, at 0230 hours the pumpdown was started. When the vacuum chamber pressure reached 1.0×10^{-4} torr the heaters were turned on to bake out the system. During the bakeout period of eight hours the temperatures of the actuator and of the static potentiometer were not allowed to exceed 190°F. Pumpdown data are shown in Table 2 and Fig. 4. After the bakeout period was completed, the chamber was allowed to cool down to room ambient temperature.

2.1.5 Static Vacuum Exposure

On March 17, 1963, at 0100 hours, the chamber pressure had reached a value of 3.0×10^{-9} torr and the eight-day static vacuum exposure period was started. The static potentiometer data, system pressure, and component temperatures were taken every four hours. These data are included in Table 2.

2.1.6 Vacuum Operation

On March 25, 1963, at 1215 hours the vacuum operation phase of the test was started. The jet vane actuator was operated for fourteen minutes while all test parameters were monitored. The same 100 cycle "noise" patterns which, during the atmospheric pressure operation, had been observed in the recorded signals from the telemetry potentiometer and the torque current were present in the same magnitude at the start of vacuum operation. The "noise" pattern remained essentially unchanged during the first 1.5 minutes of operation. During the remaining portion of the operating period, both the magnitude and the quantity of "noise" increased steadily.

After 4.7 minutes of operation, "noise" began to appear in the servo potentiometer signal. The servo potentiometer noise increased spasmodically and after fourteen minutes of operation had masked the basic signal so that it had changed from a sinusoidal wave form to an almost square wave form. At this point operation was stopped and the jet vane actuator was allowed to soak in the 10^{-9} torr environment for 1.5 hours. Data for this operating period are shown in Table 3.

After the soak period, the actuator was restarted at 1400 hours and was operated for ten minutes. At the beginning of this second period of vacuum operation the "noise" pattern for all signals was essentially the same as it had been at the beginning of the first period of vacuum operation and it did not change appreciably during the first minute of operation. During the remaining portion of the operating period both the magnitude and quantity of "noise" increased steadily in the signals from the telemetry potentiometer and the torque motor. After 3 minutes of operation, "noise" began to appear in the servo potentiometer signal. The servo potentiometer "noise" steadily increased until the signal became very erratic. At this point operation of the jet vane actuator was stopped. Data for this second operating period are shown in Table 4.

2.1.7 Operation of Actuator at Various Pressure Levels

On March 25, 1963, at 1450 hours a controlled shutdown and venting procedure was started. The diffusion pumps were turned off and the vacuum chamber pressure was allowed to rise without the addition of any venting gas. As the pressure rose the jet vane actuator was operated briefly at each pressure decade to observe the effect of each pressure increase on the operating parameters.

At a pressure of 5×10^{-6} torr the magnitude of the "noise" in the telemetry potentiometer began to decrease. At a pressure of about 2×10^{-5} torr the magnitude and quantity of "noise" in the torque motor signal began to decrease and the servo potentiometer signal began to revert to the sinusoidal wave form. Data are shown in Table 5.

2.1.8 Post Vacuum Operation

On March 25, 1963, at 1640 hours the actuator was operated for 1.5 minutes at room ambient conditions. Some noise was still evident on both the torque current and telemetry potentiometer signals. Data are shown in Table 6.

2.1.9 Post Vacuum Calibration and Checkout

On March 25, 1963, at 1700 hours the jet vane actuator and the associated instrumentation were checked and recalibrated as described in Section 8.0. The static potentiometer was reconditioned as described in Section 10.1.2 and data were taken as described in Section 9.3. The loaded bearing was checked for starting torque and no measurable change was found. Data are shown in Tables 7 and 8.

2.1.10 Component Evaluation

On March 26, 1963, at 0800 hours the jet vane actuator was disassembled for physical examination of its component parts. The Markite potentiometers and Barden bearings were examined by Mr. John L. Ham of NRC and were then sent to their respective manufacturers for further evaluation. Data from these examinations and evaluations are presented in Appendix A.

2.2 Vacuum Exposure Test No. 2

2.2.1 Introduction

Exposure Test No. 2 was performed with Aeroflex Jet Actuator, Serial No. 02, modified as described in Section 4.3 of this report; Markite Potentiometer, Serial No. 200; and Barden Bearing, Part No. SFR3BSSX112K5. Test operations were performed before, during, and after vacuum exposure to determine any change in performance characteristics.

2.2.2 Installation of Test Pieces and Checkout of Assembly

On March 26, 1963, at 1200 hours the installation and checkout sequence for Exposure Test No. 2 were started. The jet vane actuator was mounted on the vacuum chamber head and wired to the vacuum feedthrough. A stainless steel tube was welded to the actuator rear case and passed through the vacuum head. This tube was connected to a mercury "U" tube manometer which was used to monitor the pressure inside the actuator case during the initial pumpdown phase and the venting phase of the test. A clamp was mounted between the vacuum system and the manometer to close the line and isolate the manometer from the system after initial pumpdown. See Figures 5, 6, & 7. The power supply and instrumentation were checked out.

All circuits were found to be operating properly with the exception of the amplifier circuit. The trouble appeared to be in the transistor section. A JPL representative was notified and he decided to send a new amplifier to replace the faulty one.

On April 5, 1963, at 1300 hours the new amplifier arrived and was installed. The circuit was checked and Pin B on the amplifier connector lead was found to have an open circuit. Repairs were made and the circuit was re-checked and found to be operating properly.

On April 5, 1963, at 1545 hours the actuator was operated under atmospheric conditions for 6 minutes. Data are shown in Table 9. Operation was terminated by a malfunction. Circuits were then checked out again and were found to be operational but the actuator would only run intermittently. The connector on the actuator case was removed and it was found that a wire, leading from Pin B to the servo potentiometer wiper, was broken. The wire appeared to have been cut when it was stripped at the time of assembly of the actuator unit. The wire was repaired and the circuit was re-checked and found to be operating properly. The static potentiometer was conditioned as per Section 10.1.2 of the Pre-Test Procedure and was then wired to the vacuum feedthrough. The Barden bearing was mounted on a shaft and was pre-loaded with a brass fly wheel. See Figure 7.

2.2.3 Atmospheric Pressure Operation

On April 8, 1963, at 1200 hours all circuits were checked out and found operational. The recording instrumentation was checked and calibrated as per Section 8.0.

On April 8, 1963, at 1645 hours, a 12 minute period of operation at atmospheric pressure was performed. One hundred cycle noise, similar to that observed during the first actuator test, was present on the torque current and telemetry potentiometer signals. Data for the atmospheric pressure operation are in Table 9. The vacuum system was then closed and a pre-pumpdown check of all circuits was performed. The amplifier did not perform properly and the trouble was traced to over-heating transistors. Replacements were installed and on April 9, at 1335 hours, a brief operating period was started. The actuator stopped operating after 2.5 minutes due to a faulty ground connection. This condition was corrected and proper operation was resumed. Data are shown in Table 9.

On April 9, 1963, at 1400 hours the actuator was operated for 15 minutes at atmospheric pressure. During this operating period transistors in the amplifier circuit were matched to achieve the best torque current signal. The final 5 minutes of atmospheric pressure operation was run using the best matched pair of transistors. During the entire period of atmospheric pressure operation 100 cycle noise was present on the torque current and telemetry potentiometer signals. Resistance and voltage readings were taken on the static potentiometer as described in Section 9.3. The static bearing data were obtained as described in Section 9.2. The starting torque was negligible. The "U" tube manometer was installed as per Section 7.6. See Figures 5,6, and 7 and Table 10.

2.2.4 Pumpdown and Bakeout

On April 9, 1963, at 1452 hours the pumpdown was started. During the initial pumpdown, pressure in the actuator case interior was read with the mercury "U" tube manometer. See

Table 11 for initial pumpdown data of system and actuator.

On April 9, 1963, at 1550 hours the manometer clamp was closed and the manometer was isolated from the system. When the vacuum chamber pressure reached 1.0 x 10^{-4} torr the heaters were turned on to bake out the system. During the bakeout period of eight hours the temperatures of the actuator and the static potentiometer were not allowed to exceed 190°F. Static potentiometer data was taken at intervals during this period. After the bakeout was completed, the chamber was allowed to cool to room temperature. Data are shown in Table 12.

2.2.5 Static Vacuum Exposure

On April 10, 1963, at 1400 hours the chamber pressure had reached a value of 1.0 x 10^{-8} torr and the eight day static vacuum exposure period was started. The static potentiometer data, system pressure and component temperatures were taken every four hours. These data are included in Table 12.

2.2.6 Vacuum Operation

On April 18, 1963, at 1015 hours the vacuum operation phase of the test was started. The jet vane actuator was operated for 24 hours while all test parameters were monitored. The same 100 cycle noise patterns which during the atmospheric pressure operation had been observed in the recorded signals from the telemetry potentiometer and the torque current were present in the same magnitude at the start of vacuum operation. The patterns of all six signals remained essentially unchanged throughout the 24 hour operation period with the exception of a zero position shift of the actuator after 5.1 hours of operation. The zero shift was corrected by adjusting the amplifier balance potentiometer and the actuator then continued to operate with approximately the same signal magnitudes as had existed before the zero shift. After the completion of 24 hours operation the system was prepared for venting with the actuator continually operating. Data for the 24 hour operating period are shown in Table 13.

2.2.7 Operation of Actuator at Various Pressure Levels

On April 19, 1963, at 1100 hours a controlled shutdown and venting procedure was started with the actuator operating continuously. The diffusion pumps were turned off and the vacuum chamber pressure was allowed to rise without the addition of any venting gas. As the pressure rose, data was collected at each pressure decade to observe the effect of each pressure increase on the operating parameters.

At a pressure of 2.0 x 10^{-8} torr the noise level in the telemetry potentiometer and the torque current signals started to increase in magnitude. These signal "noise levels" increased as the system pressure increased. At a pressure of 28 millimeters of Hg the torque current signal was completely hidden under its noise pattern and for the first time a slight distortion in the servo potentiometer output was noticed. The vacuum system was held at a pressure of 28 millimeters of Hg for approximately one minute and the clamp on the "U" tube manometer was opened. The system was then vented to atmosphere while monitoring the actuator interior pressure as well as the operational characteristics. While venting with dry nitrogen from 28 millimeters to atmospheric pressure, the torque current signal increased until it was completely hidden in a wide noise band. Data for the vent operation are shown in Tables 11 and 14.

2.2.8 Post Vacuum Operation

On April 19, 1963, at 1238 hours the vacuum system reached atmospheric pressure and the actuator was operated for 1.5 minutes at room ambient conditions. Data for this operation are shown in Table 15.

2.2.9 Post Vacuum Calibration and Checkout

On April 19, 1963, at 1400 hours the jet vane actuator and the associated instrumentation were checked and re-calibrated as described in Section 8.0. The static potentiometer was reconditioned as described in Section 10.1.2 and data were taken as described in Section 9.3. The static bearing was checked for starting torque and no measureable change was found. Data are shown in Tables 16 and 17.

2.2.10 Component Evaluation

On April 20, 1963, at 0800 hours the jet vane actuator was disassembled for physical examination of its component parts. The Markite potentiometers and Barden bearings were examined by Mr. John Ham of NRC and were then sent to their respective manufacturers for further evaluation. Data from these examinations and evaluations are presented in Appendix A.

17

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Introduction

The conclusions are based on the test results and the subsequent evaluation of the test components and are separated into three categories: 1) The Aeroflex jet vane actuator assembly, 2) the Markite potentiometer, and 3) the Barden "Bartemp" bearing. Included in each category are recommendations for improvement of the operation of each component.

3.2 The Aeroflex Jet Vane Actuator Assembly

Two jet vane actuator assembly samples were exposed individually to a pressure environment in the 10^{-9} torr range. The operating components of one assembly were exposed directly to the vacuum environment. The operating components of the second assembly were exposed indirectly to the vacuum environment through a restricted opening. Refer to Section 4.3 for a more complete description of the test samples. The performance of the two assemblies was essentially identical during operation in air prior to vacuum exposure. The performance of the two assemblies was vastly different during operation in ultrahigh vacuum after an eight-day exposure to an ambient pressure in the 10^{-9} torr range.

The assembly in which the operating components were directly exposed to the ambient vacuum developed serious "noise" in its electrical signals after 1.5 minutes of operation. This undesirable noise level steadily increased and resulted in termination of the test after only 25 minutes of vacuum operation.

The assembly in which the operating components were indirectly exposed to the ambient vacuum operated with its electrical signal "noise" at a level little greater than that during operation in air. The noise level remained essentially the same during 24 hours of vacuum operation after which the test was terminated as scheduled.

It is concluded that the restricted opening in the second sample in combination with outgassing from the components and materials inside the actuator case resulted in a higher local pressure around the operating components. This higher local pressure reduced evaporation and decomposition of lubricating or protecting surface films whose presence prevents any metal to metal contacts which produce galling and resultant electrical noise.

It is recommended that, for reliable actuator operation following long period of static exposure to low pressures, the actuator case be at least partially sealed. Inclusion of a small amount of benign material, with a low but finite vapor pressure, inside the partially sealed actuator case should increase the length of the tolerable exposure period.

3.3 The Markite Potentiometer

Two potentiometer assembly samples were operationally tested as component parts of the two jet vane actuator assemblies and two potentiometer body samples, without wipers, were statistically tested as individual components.

The two static potentiometer bodies were exposed to similar ambient pressures in the two exposure tests. The results were essentially the same in each case. The resistance and the voltage drop across the total potentiometer, and across each of its two halves, were measured at intervals during the test. No appreciable change was found in either of these two values.

The two operational potentiometer assemblies were exposed to different ambient pressures in the two exposure tests as a result of the two different degrees of communication between the inside of the actuator case and the vacuum prevailing in the exposure chamber. The major difference observed on microscopic examination was one of wear. The tracks and wipers on the unit with restricted communication showed relatively high wear consistent with the much longer period of operation. Since the actuator signals did not develop excessive "noise" during this long operating period, wear, as such, does not appear to be the cause of noisy signals.

Each of the operating potentiometers showed orderly wear on the high resistance track and the associated wiper. Each of the potentiometer showed craters and ridges on the low resistance track and pits and smears on the associated wiper. The inspection and evaluation at Markite Corporation showed some increase in contact resistancy but that the units were still within specifications.

It is concluded that the high resistance track performs well at all pressures; that the low resistance track does not perform well in ultrahigh vacuum and is the most likely source of the noisy actuator signals. It is felt the evidence would be more clear cut if the restricted unit had not gone through a period of noisy operation, probably due to blowing around of wear dust, during the venting phase of the second exposure test. This is described in Section 2.2.7.

It is recommended that the low resistance track be replaced by either two flexible wires or a second high resistance track in series with the present high resistance track.

3.4 The Barden "Bartemp" Bearings

Four bearing samples were operationally tested as component parts of the two jet vane actuator assemblies and two bearing samples were tested under static load as individual components. The bearings were examined both visually and mechanically at National Research Corporation, and both optically and on a smooth rotor at Barden Bearing Company. No effect due to either static vacuum exposure or vacuum operation was detectable in either examination. One bearing was found to have multiple brinell marks. This bearing was difficult to remove from the actuator shaft and the brinelling undoubtedly occurred during removal.

It is concluded that the "Bartemp" bearings operated well at all pressures.

4.0 TEST COMPONENTS

4.1 Description of Test Components

The test components consisted of seven items: two Aeroflex jet vane actuator assemblies; two Barden precision ball bearings, duplicates of one of the actuator assembly parts; and three Markite potentiometers, duplicates of one of the actuator assembly parts.

4.2 Identification of Test Components

The test components and part numbers are listed below:

Description	Manufacturer	Part No.	S/N	Quantity
Jet Vane Actuator	Aeroflex	---	01	1
Jet Vane Actuator	Aeroflex	---	02	1
Potentiometer	Markite	---	100	1
Potentiometer	Markite	---	200	1
Potentiometer	Markite	---	2G-834	1
Ball Bearing	Barden	SFR3BSSX112K5	---	2

4.3 Aeroflex Jet Vane Actuators

The jet vane actuators were standard units individually modified for each test. Actuator Serial No. 01 was modified by removal of the shaft seal and the back cover to allow for full vacuum exposure of the interior components. See Figures 2 and 3. Actuator Serial No. 02 was modified by removal of the shaft seal and by attachment of a pressure measuring device as described in Section 6.3 of this report. See Figures 6 and 7.

4.4 Markite Potentiometers

The Markite potentiometers were standard units with the wiper removed. Serial Numbers 100 and 200 were exposed to the vacuum environment. Serial Number 2G-834 was not exposed to the vacuum environment and was used as a comparison tool to determine any vacuum effect.

4.5 Barden Precision Ball Bearings

The ball bearings were standard Bartemp No-lube bearings.

5.0 TEST FACILITIES

5.1 Vacuum System

The tests were conducted in NRC Ultrahigh Vacuum System No. 146. The vacuum chamber is 14 inches in diameter and 18 inches deep. The chamber is pumped by a liquid nitrogen trap, a six-inch diffusion pump, a two-inch diffusion pump and a six-cubic foot mechanical pump in series. This system is capable of reaching a pressure of 1.0×10^{-9} torr when clean, dry, empty, and at room temperature. See Figures 1 and 5.

5.2 System Pressure

Pressure in the main chamber of the system is measured with a hot filament ionization gauge whose output is read with a standard NRC ionization gauge control box. Secondary pressure gauges are located throughout the pumping manifold to monitor pressures at each pumping station.

6.0 TEST FIXTURE AND EQUIPMENT

6.1 Jet Vane Actuator Mount

The jet vane actuator mount consisted of a stainless steel plate fitted with suitable mounting holes for the actuator and with two stops which restricted the jet vane actuator rotation to $\pm 25^{\circ}$. This mounting plate was welded to the vacuum surface of an 18-inch diameter flange which served as the vacuum chamber top-cover. A twenty wire feedthrough was installed in the center of the flange for electrical connections to the actuator. See Figures 2 and 3.

6.2 Power Supply

The jet vane actuator was operated by an amplifier which was supplied by Jet Propulsion Laboratory. This amplifier was powered by wet cell batteries. The batteries supplied a bias of plus and minus 22 volts DC to the amplifier and 6 volts DC across the servo potentiometer. Motion to the jet vane actuator was supplied by a Kronite signal generator which supplied 2 cycle, 0 to 6 volts, RMS current. Power to the telemetry potentiometer was supplied by a 6 volt wet cell battery. See Figures 10 and 12.

6.3 Actuator Case Pressure Indicator

After completion of the first exposure test, the chamber cover and the actuator to be tested were modified so that during the pumpdown and venting phases of the second exposure test the pressure inside the actuator unit could be measured. The modifications performed and the pressure measuring equipment used are described below and shown in Figures 6 and 7.

A stainless steel cover was constructed to replace the existing aluminum cover on the back of the actuator case. A hole was drilled in this stainless cover to receive a 1/4-inch stainless steel tube. A similar hole was drilled in the vacuum chamber cover. A shaped and fitted length of stainless tubing was welded into the actuator cover and, after thorough cleaning, this assembly was attached to the actuator. The actuator was then mounted in test position with the free end of the tubing passing through the hole in the vacuum chamber cover. The tubing was then welded to the vacuum chamber cover.

On the outside of the vacuum chamber a pressure measuring system was provided for connection to the free end of the stainless tubing when the cover was in position on the chamber. This pressure measuring system consisted of a "U" tube mercury manometer, a trap containing a mixture of dry ice and acetone to prevent diffusion of mercury vapor into the vacuum chamber, and a clamp to isolate the measuring system from the vacuum chamber during periods when the measuring system was not in use.

7.0 INSTRUMENTATION

7.1 Oscilloscope and Camera, Model No. 535

A Tectronic oscilloscope, was used to visually examine the feed-back signal from the servo potentiometer. A Dumont oscilloscope camera was used to take photographs of the feed-back signal at selected times. See Figures 1 and 5.

7.2 Low Frequency Filter

A low frequency resistance-capacitance filter was constructed according to specifications for the "O" filter found in the Markite Corporation publication entitled "Test Procedure for Filtered Output."* A schematic diagram of the "O" filter is shown in Figure 11. This low frequency filter was wired into the telemetry potentiometer circuit so that the two cycle carrier from the Kronite signal generator was removed from the potentiometer output signal leaving the higher frequency "noise" signals clearly defined. Figure 12 shows the filter placement in the instrumentation circuit.

7.3 Multi-Channel Recorder

A Schwarzer multi-channel recorder was used to record six signals simultaneously. In the first exposure test the six recorded signals were: (1) the input voltage to the amplifier, (2) the feed-back voltage from the servo potentiometer, (3) the pressure in the vacuum system, (4) the temperature of the actuator case, (5) the current through the torque motor, and (6) the noise from the telemetry potentiometer.

*Markite Corporation Engineering Report No. P-429, pages 5 and 6.

In the second exposure test the output voltage from the telemetry potentiometer was recorded instead of the temperature of the actuator case. All other signals recorded in the second test were the same as had been recorded in the first test. Channel identification and calibration factors are listed in the recorder calibration section. See Section 8.2 and Tables 8 and 17.

7.4 Temperature Potentiometer

A Leedsand Northrup direct reading potentiometer, Model 8693, was used to read out two copper constantan thermocouples indicating the temperatures of the jet vane actuator case and the static Markite potentiometer.

7.5 Vacuum Tube Voltmeter

An RCA Vacuum Tube Voltmeter, Model WV-98A, was used to measure voltage and resistance across the static potentiometer.

7.6 "U" Tube Manometer (See Figure 7)

In Test No. 2 a "U" Tube Mercury Manometer was attached through a cold finger to the 1/4" diameter tube which passed through the vacuum chamber cover to the actuator back cover. The manometer was used to monitor the actuator interior pressure during the pump-down and venting phases of the test. The cold finger was chilled with a dry ice and acetone mixture to trap mercury vapor so it could not enter the vacuum system and the actuator. A clamp was placed between the cold finger and the vacuum system to isolate the manometer from the vacuum system when the manometer had reached its maximum detectable pressure drop. The assembly is shown in Figures 6 and 7.

8.0 CALIBRATION OF EQUIPMENT

8.1 Thermocouples

All thermocouples were calibrated with the Leeds & Northrup potentiometer in ice water and in boiling water. Thermocouples selected for use read within $\pm$ 1°F of the true temperature and were used without correction during the tests.

8.2 Multi-Channel Recorder

All six channels used in the two exposure tests were calibrated. Calibration was performed by feeding into the recorder a known signal from the Leeds & Northrup millivolt potentiometer and measuring the resulting output signal. Tables 8 and 17 show for the respective exposure tests the parameters measured, the channels used, and the calibration factor per centimeter of chart traverse.

8.3 Torque Motor

The torque motor in each jet vane actuator was calibrated before and after its vacuum exposure test. The relationship between the input current and the output torque was determined. The calibration was performed by suspending several individual dead weights from the torque motor shaft and then applying the minimum voltage to the motor to enable it to just lift each weight. The weights were suspended from a fine cord which was wound around a small drum on the torque motor shaft. The current required to lift each weight was measured. Figure 13 shows the calibration set-up. Calibration data are listed in Tables 7 and 16 and are plotted in Figures 14 and 15.

8.4 Vacuum Tube Voltmeter

Both the voltage and resistance scales of the RCA vacuum tube voltmeter were calibrated. The voltage scale was calibrated over the range from 0 to 45.0 volts with a laboratory standard voltmeter. The resistance scale was calibrated over the range from 0 to 30K ohms with 1% precision resistors.

9.0 PROCEDURE FOR DATA TAKING

9.1 Jet Vane Actuator Data

9.1.1 Calibrate the torque motor as described in Section 8.3

9.1.2 Calibrate the Schwarzer recorder as described in Section 8.2

9.1.3 Calibrate the Leeds & Northrup potentiometer as described in Section 8.1

9.1.4 Operate the jet vane actuator and record data on the Schwarzer recorder and the Leeds & Northrup potentiometer.

9.2 Ball Bearing Data

9.2.1 Place the static bearing on the mounting shaft and install the pre-load disc. See Figures 2, 3, and 7.

9.2.2 Measure the torque necessary to rotate pre-load disc before and after vacuum exposure.

9.3 Potentiometer Data

9.3.1 Calibrate the RCA Vacuum Tube Voltmeter as described in Section 8.4.

9.3.2 Measure the resistance across the total resistor. See Figure 16.

9.3.3 Measure the resistance across the center tap and each end of the total resistor. See Figure 16.

9.3.4 Hook up the D.C. batteries across the total resistor. See Figure 16.

9.3.5 Measure the voltage drop across the total resistor. See Figure 16.

9.3.6 Measure the voltage drop across the center tap and each end of the total resistor. See Figure 16.

9.4 Vacuum System Data

9.4.1 Check the zero point on all vacuum gauges.

9.4.2 Set the emission current for all ionization gauges.

9.4.3 Record the pressure of the main chamber and of each pumping station.

10.0 TEST PROCEDURE

10.1 Pre-Vacuum Operation

10.1.1 Operate the jet vane actuator in the received condition.

10.1.2 Condition the potentiometer for 8 hours at 70°C, put it in a desiccator for 8 hours and then record data as described in Section 9.3.

10.1.3 Install the jet vane actuator, the static bearing and the static potentiometer on the the test fixture.

10.1.4 Connect and check out all the electrical circuits.

10.1.5 Calibrate the torque motor as described in Section 8.3.

10.1.6 Calibrate all readout equipment as described in Section 8.0.

10.1.7 Operate the jet vane actuator at ambient room conditions and atmospheric pressure. Record data as described in Section 9.1.4.

10.1.8 Record potentiometer data as described in Section 9.3.

10.2 Ultrahigh Vacuum Operation

10.2.1 Pump down the vacuum system after checking operation of all equipment.

10.2.2 Start an 8-hour bakeout of the system when the chamber pressure reaches the 10^{-4} torr range. Hold the temperature of the jet vane actuator case and the static potentiometer below 190°F during the bakeout.

10.2.3 Pump the chamber down to 1.0×10^{-8} torr and hold the pressure at or below this value for 8 days. Do not operate the jet vane actuator during this entire period.

10.2.4 Record the system data, vacuum and potentiometer data every 4 hours.

10.2.5 Calibrate the Schwarzer recorder, as described in Section 8.2, just before start of jet vane actuator operation.

10.2.6 Record the vacuum system data and the potentiometer data just before the start of jet vane actuator operation.

10.2.7 Operate jet vane actuator at the conclusion of the 8-day vacuum exposure period. Continue this operation until a definite deterioration pattern in the recorded signals is established. If the recorded signal patterns do not change radically from those obtained during pre-vacuum operation, operate unit for a total period of 24 hours.

10.2.8 Record the vacuum system data and the potentiometer data at the conclusion of the jet vane actuator operation.

10.3 Vacuum Operation During Venting

10.3.1 Let the system pressure rise slowly by a controlled shutdown procedure. Maintain liquid nitrogen in the pumping manifold trap.

10.3.2 Operate the jet vane actuator at each pressure decade from the 10^{-9} torr range to atmospheric pressure, if possible, and record data.

10.3.3 Record the potentiometer data at atmospheric pressure.

10.4 Post Vacuum Operation

10.4.1 Operate the jet vane actuator at atmospheric pressure and record data.

10.4.2 Remove the jet vane actuator, the static bearing, and the static potentiometer from the test fixture and examine them for any vacuum effects.

10.4.3 Re-condition the static potentiometer at 70°C for 8 hours, place it in a desiccator for 8 hours, and then record data as described in Section 9.3 of this report.

10.4.4 Disassemble jet vane actuator and examine it for any effects, on either materials or components, due to operation in vacuum.

10.5 Additional Procedure for Test No. 2 Only

10.5.1 Connect the "U" tube manometer to the system as shown in Figure 7.

10.5.2 Record the actuator case pressure, as indicated by the manometer, at intervals during the initial pumpdown.

10.5.3 Isolate the manometer from the system by clamping it off when the actuator case pressure drops below 2 millimeters.

10.5.4 During venting of the system with dry nitrogen, release the clamp in the manometer line at a system pressure of approximately 10 torr.

10.5.5 Record the actuator case pressure at intervals as the system pressure increases from 10 torr to 700 torr.

APPENDIX A

1.0 EXAMINATION OF THE MARKITE POTENTIOMETERS USED IN THE VACUUM TESTS OF TWO AEROFLEX JET VANE ACTUATORS

1.1 Examination at National Research Corporation

The potentiometers consisted of discs of a black non-metallic material of unknown composition. They were about two inches in diameter and 1/4 inch thick and had two concentric raised ridges on one side. One of these ridges was about 5/8 inches in diameter and the other about 1 1/2 inches in diameter. One of the discs is shown in the photograph of Fig. 2, Appendix C. Four small cylindrical metal contacts ("wipers") slide on these ridges ("tracks") as the actuator turns; two on the inside track and two on the outside track. The outer ridge represents the resistance element of the potentiometer and has six lead wires attached to it. The inner ridge, has two lead wires attached to it, and serves primarily as a slip ring. Fig. 1A shows the geometrical arrangement of the points of lead wire attachment and the colors of the lead wire insulation.

Four such potentiometers were examined; two of these had been baked in vacuum and two had been operated in vacuum after baking as described in the text of this report. The metallic wipers of those operated in vacuum were also examined.

After examination at magnifications up to 30 diameters, under a binocular microscope, photomicrographs at 200X were taken at two spots on each track and at the contact point of each metallic wiper. The general area represented by each photograph can be ascertained by reference to Fig. 1A. The photomicrographs of each track and wiper are shown in Figs. 2A through 13A.

The designation "Black Side" opposite a photograph signifies that it represents an area near the middle of the side of the track to which the black wire is attached, etc. The four wipers lie on a common line which oscillates about orange and black within the green-lavender and gray-white limits.

The outside tracks at 200X were very similar in appearance whether run in vacuum or not. However, at lower magnification under the binoculars, differences in amount of wear were apparent. All showed some flattening and some wear debris in the form of brown powder adhering to the sides of the ridge; but the unit run for 24 hours showed considerably more wear than the one run 1/2 hour even though electrical noise level was low for a large portion of the 24 hour period whereas noise developed early in the 1/2 hour period.

The inside tracks at 200X proved to be of two different types. Those run in vacuum appeared to be filled with metallic particles whereas those not run in vacuum looked just like the outside tracks. Wear on the metal filled inside rings appeared to be smaller than that on the outside rings and fewer metal particles are visible on the worn flat part than on the adjacent round parts of these tracks. At a few spots it appeared that metal particles had been torn out leaving pits.

The appearance of the wipers at 200X is perhaps more revealing than that of the tracks. The outside wipers run 24 hours showed more wear than those run 1/2 hour as would be expected. However, they are smooth in the direction of motion revealing very few transverse cracks, scratches, edges or pits.

The inside wipers show less wear but are far from smooth in the direction of motion. They look as if metal transfer had occurred in both directions in an uneven manner leaving pits and what looks like smeared on soft metal from the inside tracks. This condition is quite apparent in the 24 hour test, but the pictures for the 1/2 hour test are less revealing. It seems probable that contact was intermittent on the inside tracks due to metallic adhesion and that the electrical noise originated on the inside rather than on the outside tracks.

The metal particles in the inside ring may be necessary to obtain the desired resistance but if not, i.e.,if the inside ring can also be used as part of the high resistance circuit, it is recommended that potentiometers like those not run in vacuum (S/N 100 and S/N 200) be used, since they appear to have no metal particles in their inside rings.

Alternatively, it is recommended that a flexible strip or wire of Cu-Be, bronze, or other suitable metal with low damping capacity, high conductivity, and fatigue resistance be used instead of the inside ring and wiper.

1.2 Examination at Markite

The four potentiometers and two wiper assemblies were returned to Markite for visual examination and for comparison of electrical characteristics with data taken before vacuum testing. The letter of transmittal from National Research Corporation is shown as Figure 14A, the letter of reply from Markite Corporation is shown as Fig. 15A, and the Markite recorder tracings of the evaluation tests are shown in Figs. 16A through 21A.

2.0 EXAMINATION OF THE BARDEN BEARINGS USED IN THE VACUUM TESTS OF TWO AEROFLEX JET VANE ACTUATORS

The six Barden bearings were returned to the Barden Corporation for evaluation following the testing program. The letter of transmittal from National Research Corporation is shown as Fig. 22A and the letter of reply from Barden Corporation is shown as Fig. 23A.

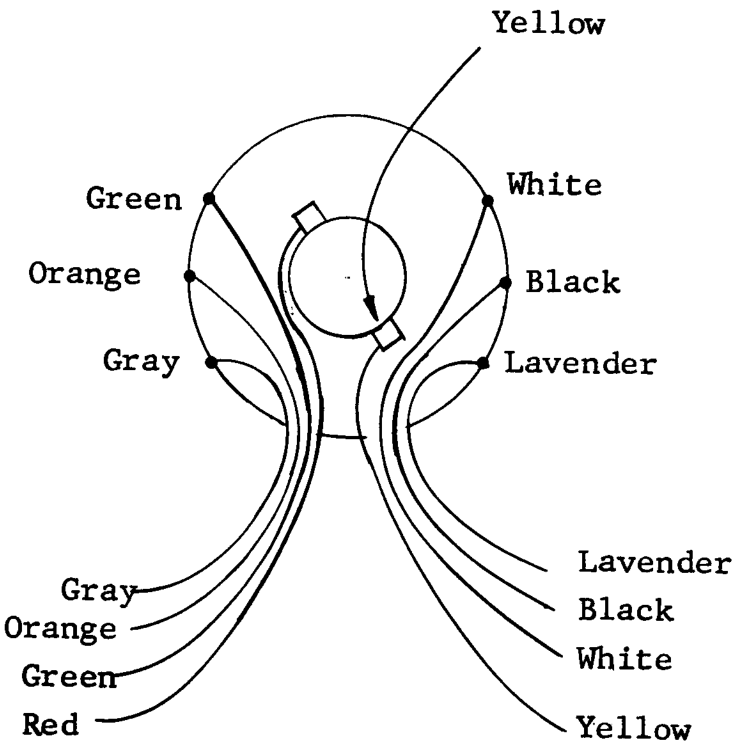
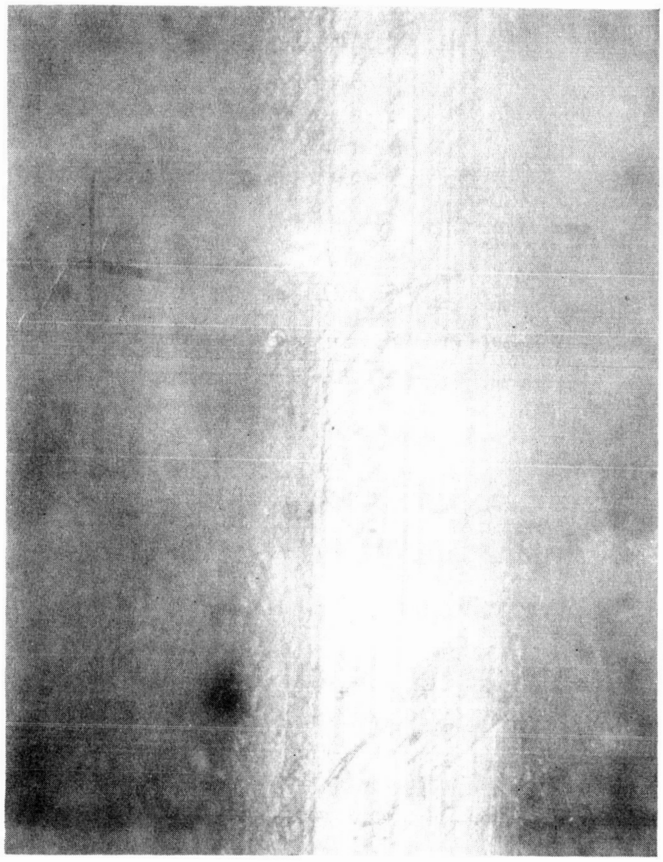
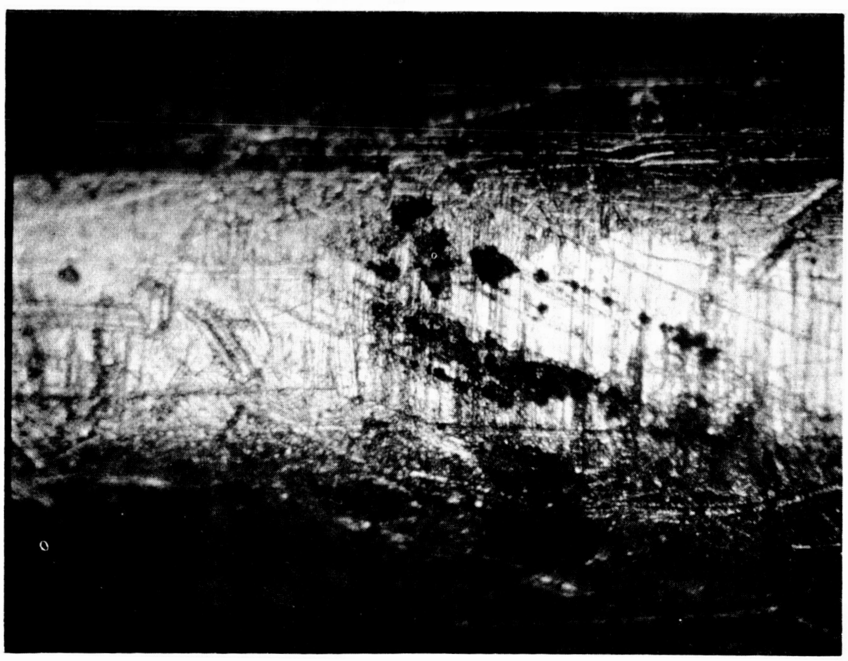


FIGURE 1A - WIRING SCHEMATIC OF MARKITE POTENTIOMETER

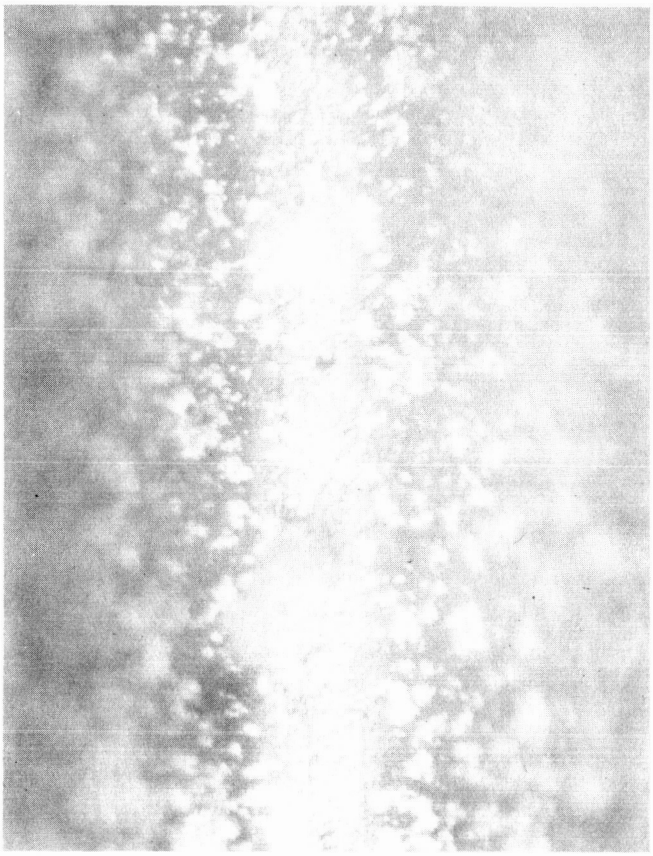


Track

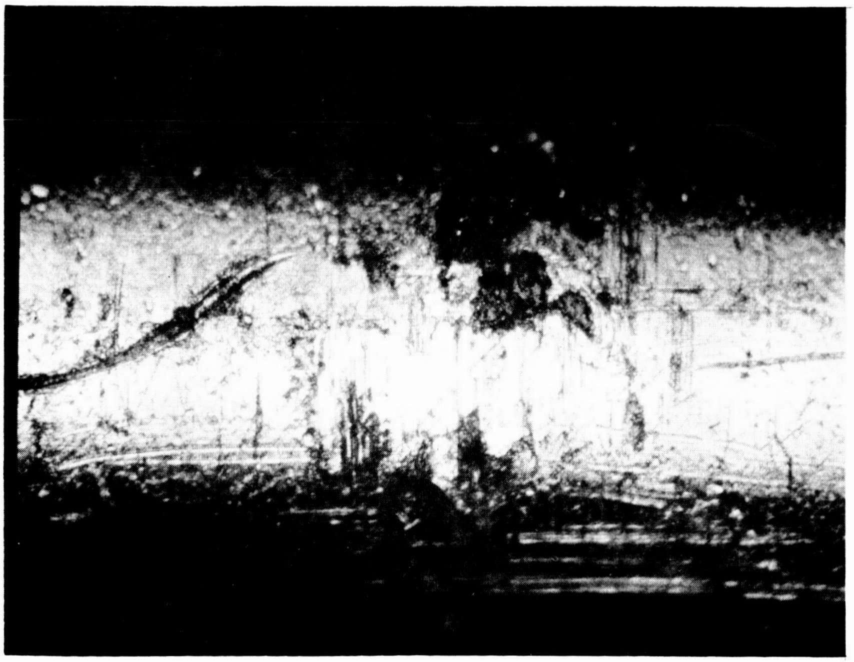


Wiper

FIGURE 2A Actuator No. 01 - Pot. No. 2F7944 - Outside Track (Orange Side) - X200 - Ran in vacuum, 1/2 hour

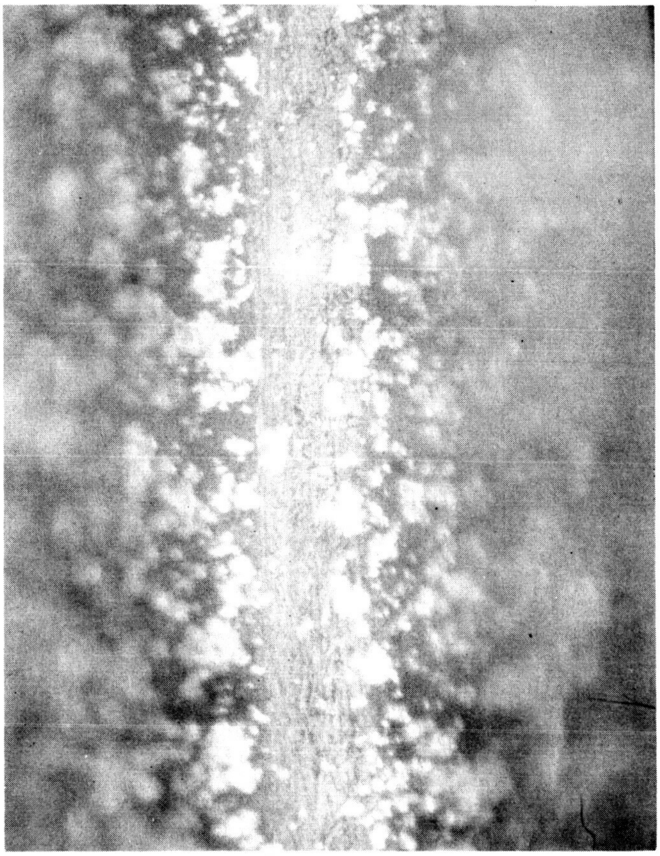


Track



Wiper

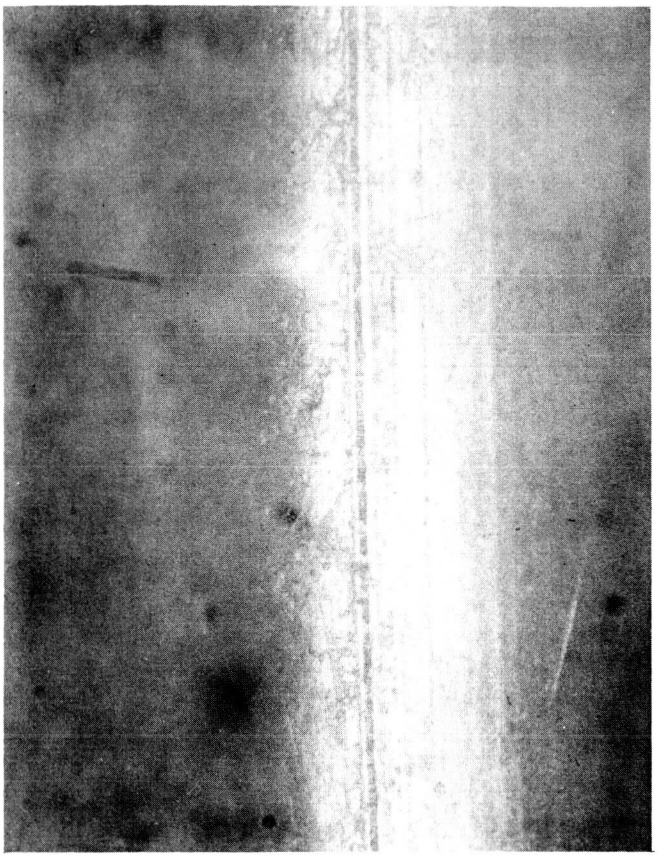
FIGURE 3A Actuator No. 01 - Pot. No. 2F7944 - Inside Track (Red Side) - X200 - Ran in vacuum, 1/2 hour



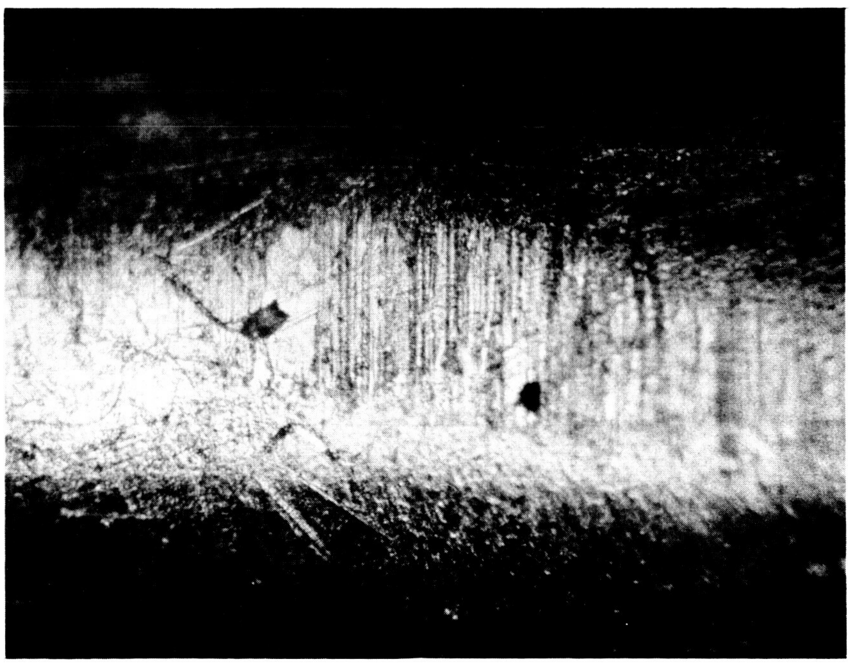
Track

Wiper

FIGURE 4A Actuator No. 01 - Pot. No. 2F7944 - Inside Track (Yellow Side) - X200 - Ran in vacuum, 1/2 hour

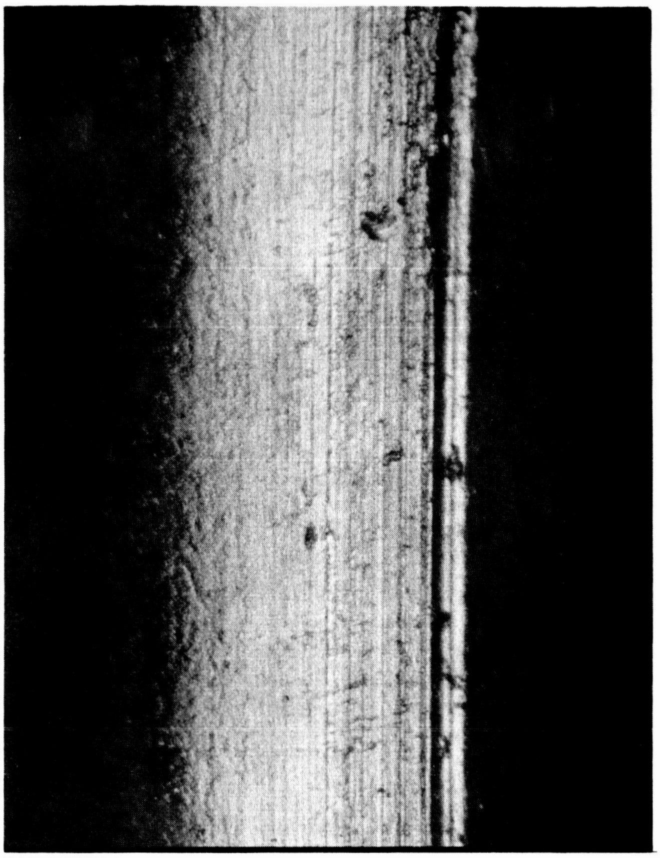


Track

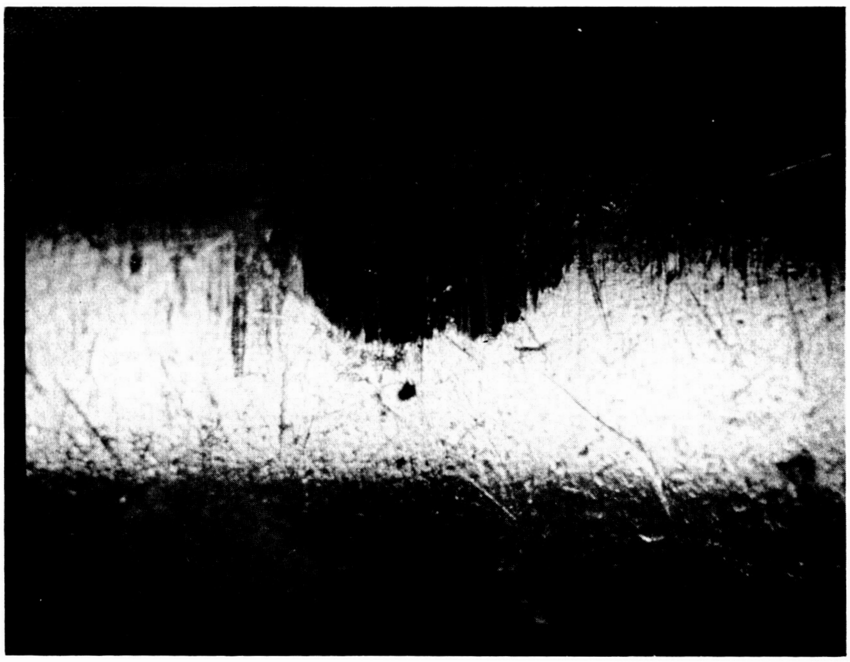


Wiper

FIGURE 5A Actuator No. 01 - Pot. No. 2F7944 - Outside Track (Black Side) - X200 - Ran in vacuum, 1/2 hour



Track



Wiper

FIGURE 6A   Actuator No. 02 - Pot. No. 2F1003 - Outside Track (Orange Side) - X200 - Ran in vacuum, 24 hours

Track

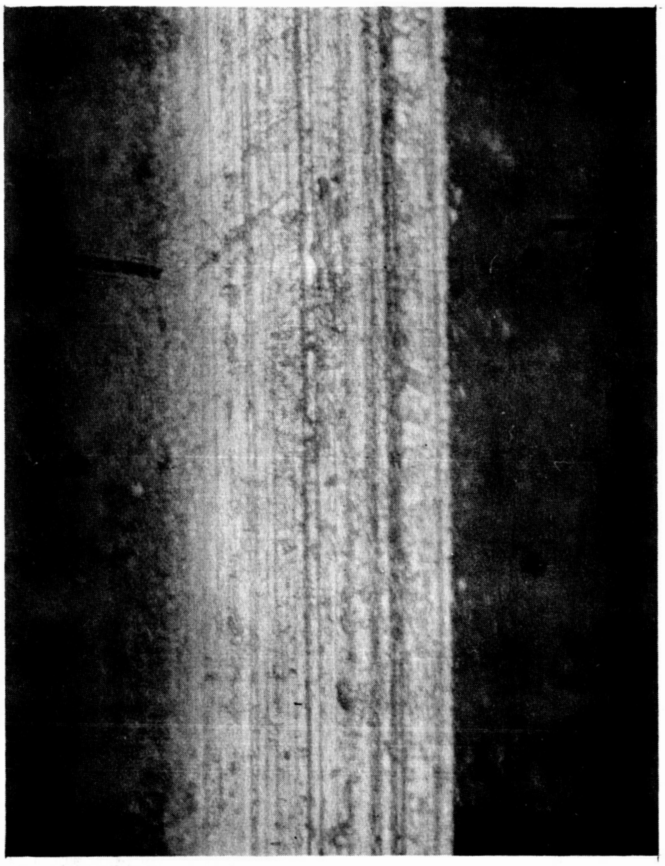
Wiper

FIGURE 7A Actuator No. 02 - Pot. No. 2F1003 - Inside Track (Red Side) - X200 - Ran in vacuum, 24 hours

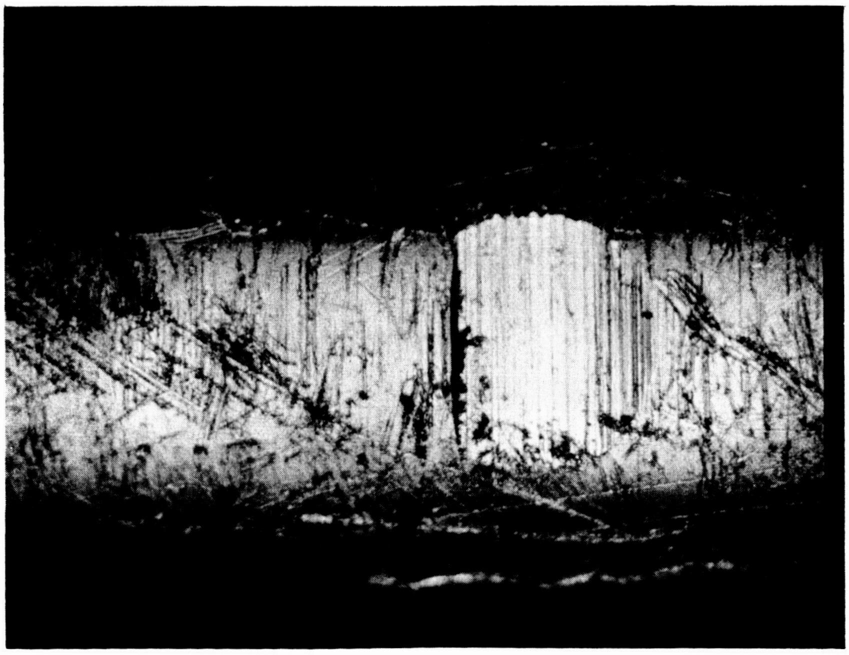
Track

Wiper

FIGURE 8A Actuator No. 02 - Pot. No. 2F1003 - Inside Track (Yellow Side) - X200 - Ran in vacuum, 24 hours

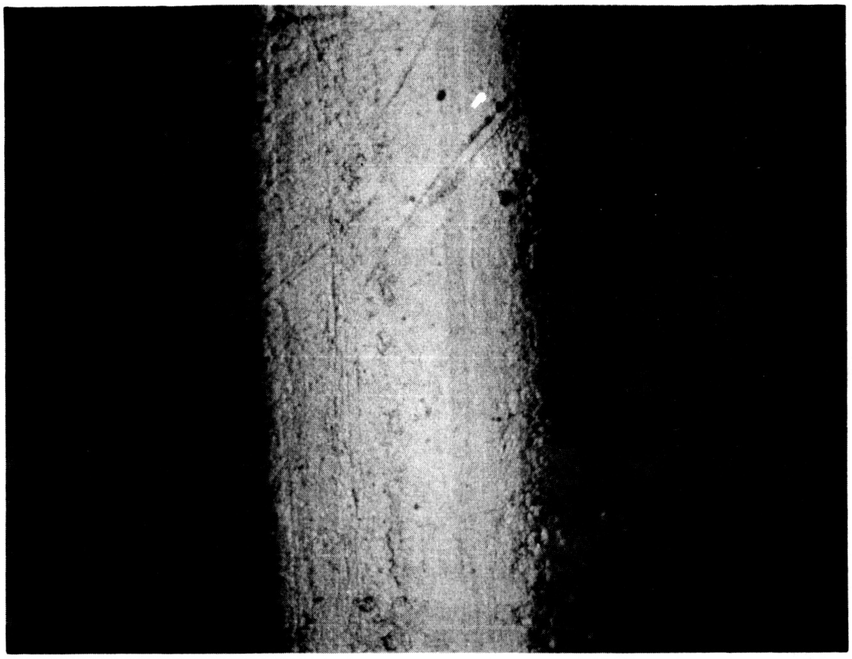


Track

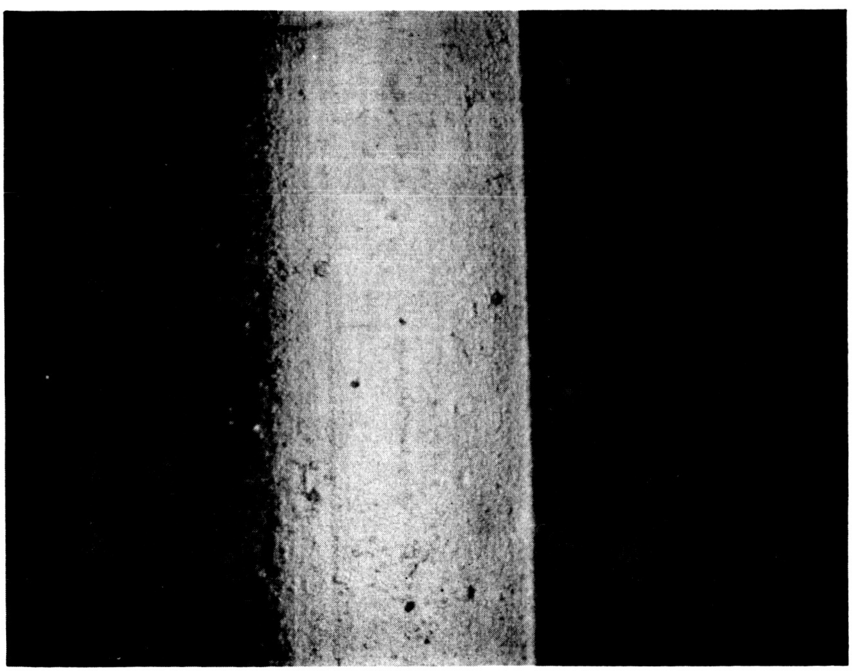


Wiper

FIGURE 9A Actuator No. 02 - Pot. No. 2F1003 - Outside Track (Black Side) - X200 - Ran in vacuum, 24 hours

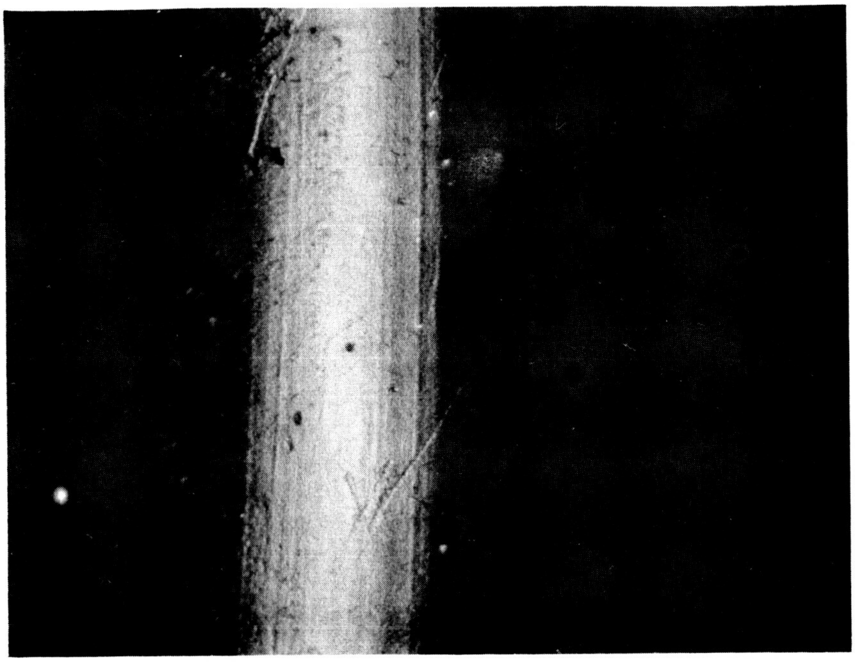


Orange
Side

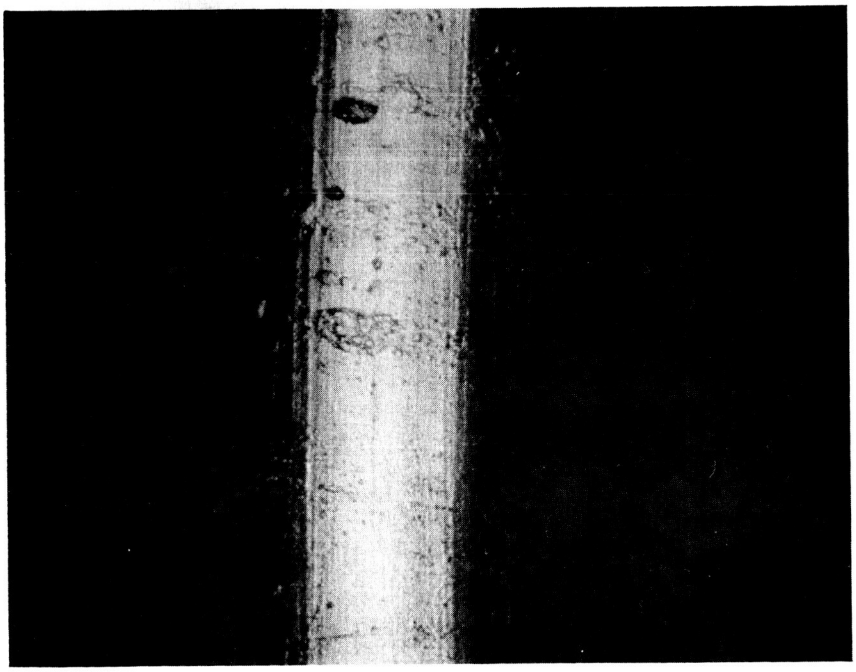


Black
Side

FIGURE 10A Outside Track - Pot. No. S/N 100 - X200 - Baked out in vacuum - Not run in vacuum

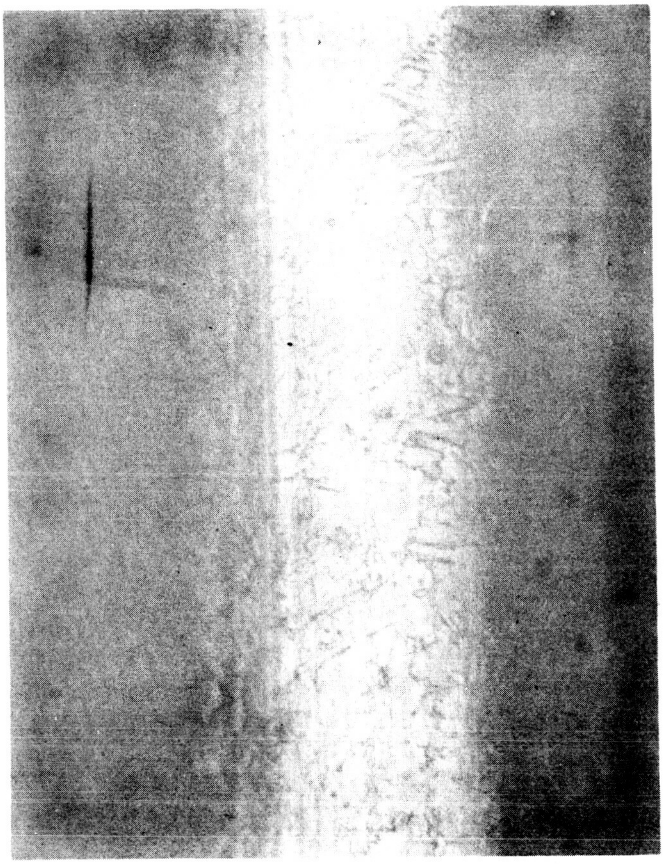


Red
Side

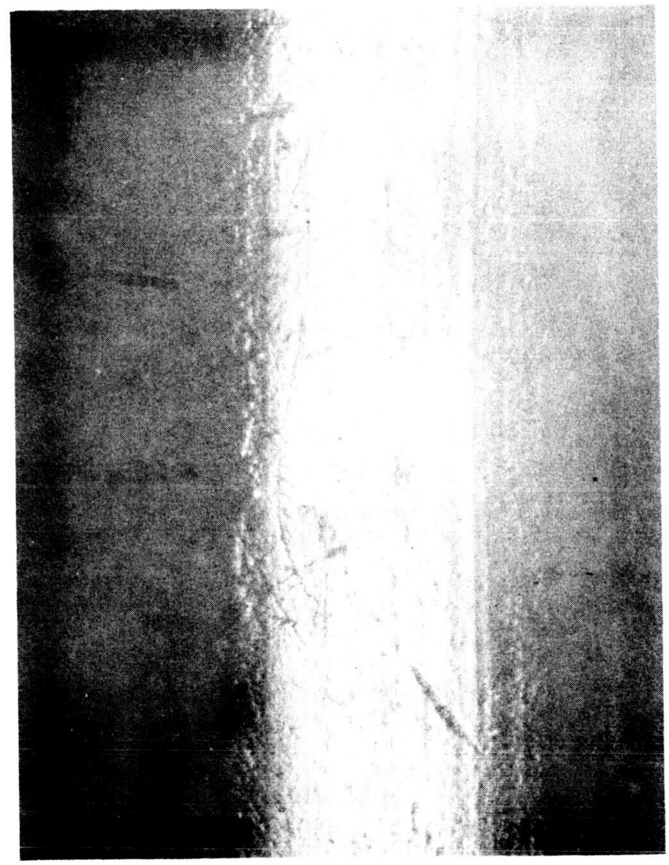


Yellow
Side

FIGURE 11A Inside Track - Pot. No. S/N 100 - X200 - Baked in vacuum - Not run in vacuum

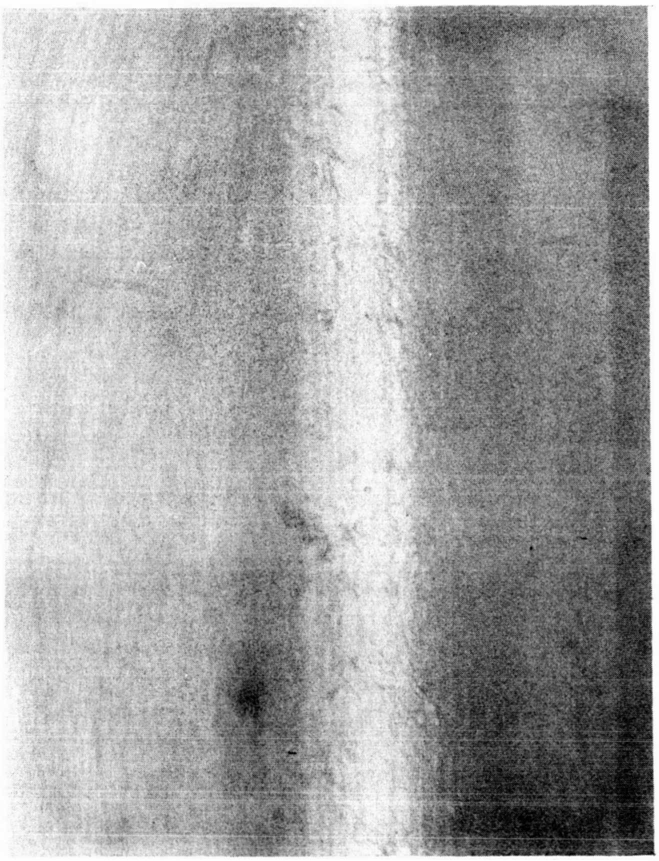


Orange Side

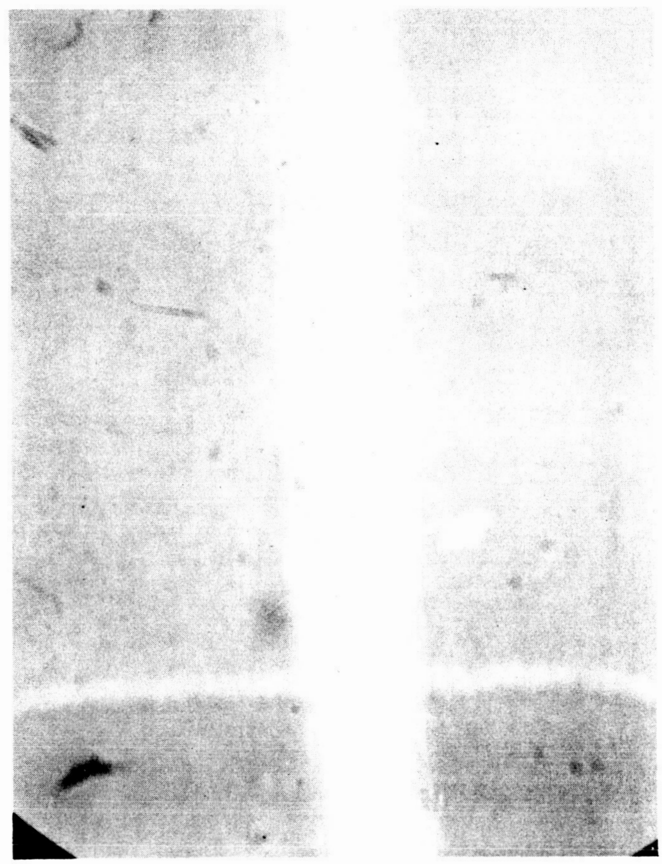


Black Side

FIGURE 12A Outside Track - Pot. No. S/N 200 - X200 - Baked in vacuum - Not run in vacuum



Red Side



Yellow Side

FIGURE 13A Inside Track - Pot. No. S/N 200 - X200 - Baked in vacuum - Not run in vacuum

RESEARCH DIVISION
NATIONAL RESEARCH CORPORATION
70 MEMORIAL DRIVE
CAMBRIDGE 42, MASSACHUSETTS

May 6, 1963

Mr. Hans Wormser
Markite Corporation
155 Waverly Place
New York 14, New York

Dear Sir:

In connection with your telephone conversation with Mr. John Ham of NRC on May 2, 1963, I am enclosing four Markite potentiometers and two wiper assemblies.

C O P Y

These components have been subjected to test in a vacuum environment. The exposure conditions of each component are listed below.

Actuator, Serial No. 01 (Potentiometer No. 2F7944 and Wiper No. 2F7944) was operated in air for approximately 10 minutes and then exposed to a vacuum bakeout at 190°F for 8 hours. This was followed by an 8-day soak period at 3×10^{-9} torr. At the conclusion of the 8-day soak the unit was operated until a failing trend was established. The unit showed signs of failure after 1 1/2 minutes of operation. The total vacuum operation time was 30 minutes. Upon completion of the vacuum test the unit was returned to room conditions where a 5 minute test was performed.

Actuator, Serial No. 02 (Potentiometer No. 2F1003 and Wiper No. 2F1003) was tested under the same conditions as Serial No. 01 except the vacuum test lasted for 24 hours and was terminated before any definite failure pattern could be established.

Potentiometers, Serial Nos. 100 and 200, were exposed to the vacuum conditions listed above only.

This information should assist you in your evaluation of the effects due to vacuum exposure and operation of your units. We would appreciate receiving a letter from you stating your findings which will then be incorporated in our report along with our evaluations. If further information is required, please feed free to contact Mr. John Ham or me here at NRC.

Very truly yours,

Rosario P. Giammanco

FIGURE 14A

MARKITE CORPORATION

MANUFACTURERS OF MARKITE POTENTIOMETERS

TELEPHONE
OREGON 5-1384

155 WAVERLY PLACE
NEW YORK 14, N.Y.

June 6, 1963

National Research Corporation
70 Memorial Drive
Cambridge 42, Massachusetts

Attention: Mr. Rosario P. Giammanco

Dear Ross,

In accordance with our conversation, we have re-evaluated the potentiometer elements which you returned after completing your vacuum test as reported in your letter of May 6, 1963. We examined these units visually under a 20 power microscope and tested them in a manner similar to that which was used in the original test before the units were shipped to you.

Our visual examination showed no visible effect of the hard vacuum exposure. Both the resistance and the take-off tracks were in good condition without any signs of deterioration. Under our magnification I also could not see the slight wear-in pattern on the brush block wipers, which you reported seeing under much larger magnification. As I indicated on the telephone, a wear-in pattern on these precious metal wipers is a normal condition of operation, since the initial contact area is merely the intersection of two lines.

All the elements were electrically continuous and their contact resistance showed no unusual pattern. Serial No. 2F7944 showed an increase of 3.5% and 4.2%, respectively, in the track resistances of the violet and white and the green/white and gray sides, respectively. The linearity pattern on the violet and white side was practically the same as it had been originally, but on the gray and green/white side, the linearity pattern was somewhat changed and the linearity apparently increased from 0.36% to 0.54%. The final condition, however, still is easily within the original specification. The two

FIGURE 15A

portions of element No. 2F1003 increased 6.9% and 4.3% in resistance, respectively. The linearity traces show slight changes, but again, the potentiometers are within specification after the test. The only apparent reason for an increase in resistance is the possibility that these units were less humid when originally tested than they are now, several weeks after the vacuum test. We would have expected a resistance decrease in the actual vacuum test and you may have some data which confirms or refutes that opinion.

If some condition in the potentiometer caused the failure in the system test under hard vacuum, it appears that this condition was transitory and disappeared before the units were returned to us. To the best of our knowledge and belief, the units, as tested by us, should perform satisfactorily against your original specification and we hope that you have been able to analyze the results of your test in such a way as to determine definitely the cause of the operating difficulties.

If we can be of any further assistance to you, please feel free to contact us. At your request we are returning to you the elements and brush blocks, Serial Nos. 2F1003 and 2F7944 along with copies of the original and re-run data sheets.

Thank you for this opportunity to work with you. We hope that we have been able to be of some assistance to you.

Sincerely yours,

Hans H. Wormser

Hans H. Wormser
Chief Project Engineer

HHW/ea
Enclosures

7

FIGURE 15A (Cont.)

M-113

MARKITE
POTENTIOMETER
PATS. PEND.

TYPE 8.5 9 8

SER. NO. 2F 1003

NOISE OK

LINEARITY SEE TRACE

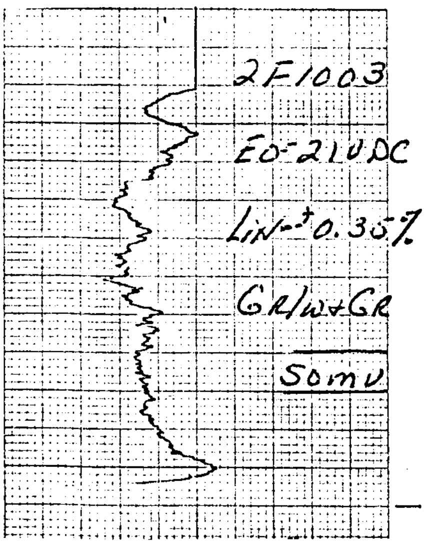
INSULATION RESISTANCE @ 500 VDC = 7 1000 MEG

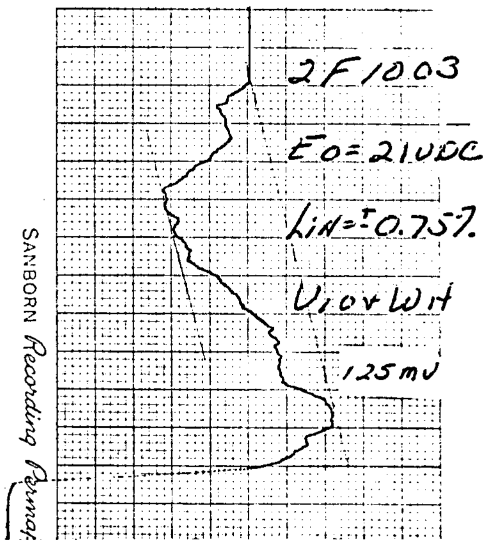
RESISTANCE V/O+W/H 20.15K 1.34 +6.9%

GR/W+GR 20.16 K 0.82 +4.3%

DATE 5-29-63 19

P.R.O.





58

FIGURE 16A

M-113

MARKITE
POTENTIOMETER
PATS. PEND.

TYPE 8598

SER. NO. 2F1003

NOISE OK

LINEARITY SEE TRACE

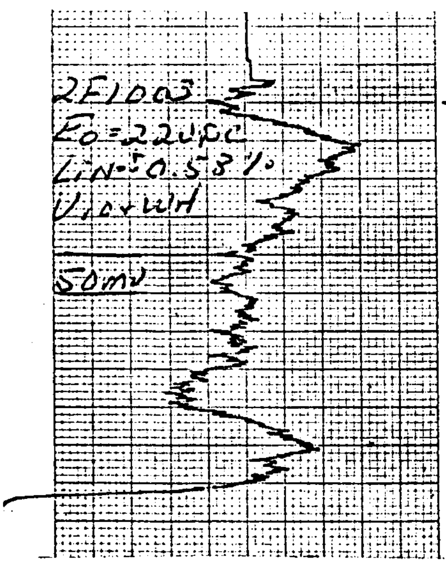
INSULATION RESISTANCE @ 1500 VDC = [illegible]

RESISTANCE GRAY + GR+WH - 19.34K

VIO + WH - 18.81K

DATE 12-27-62

P.R.O. 1999-05 M 19



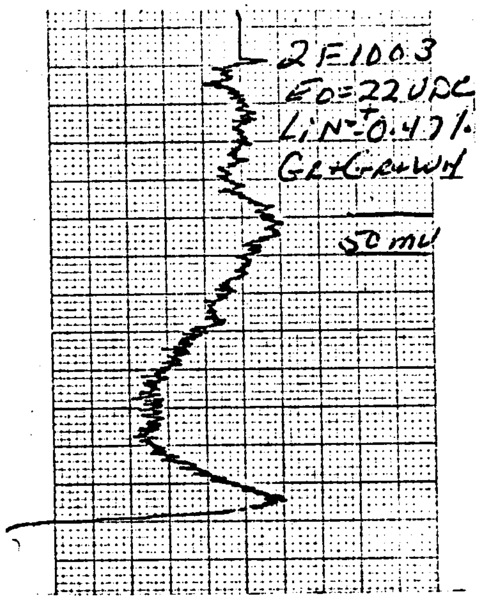


FIGURE 17A

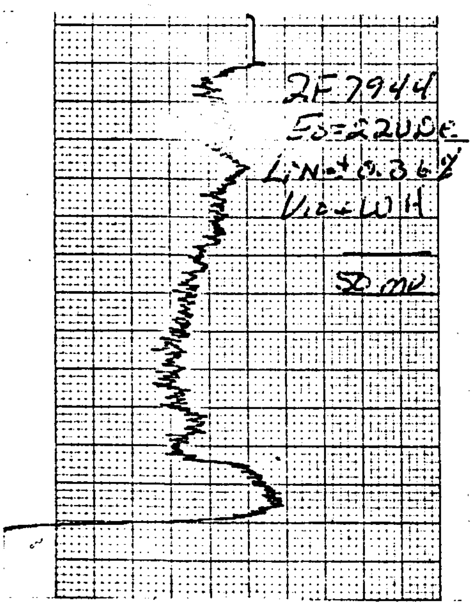
M-113

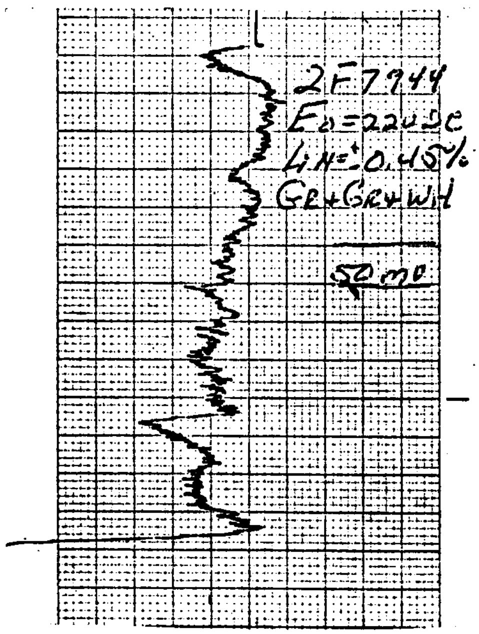
-MARKITE
POTENTIOMETER
PATS. PEND.

TYPE 8598
SER. NO. 2F7944
NOISE OK
LINEARITY SEE TRACE
INSULATION RESISTANCE @ 1500 VDC = [illegible]
RESISTANCE Gray + Gr + WH. - 20.49K
Vio. + WH - 20.09K

DATE 12-27-62
P.R.O. 1999-05

M 19





M-113

MARKITE
POTENTIOMETER
PATS. PEND.

TYPE 8598

SER. NO. 2F 7944

NOISE OK

LINEARITY SEE TRACE

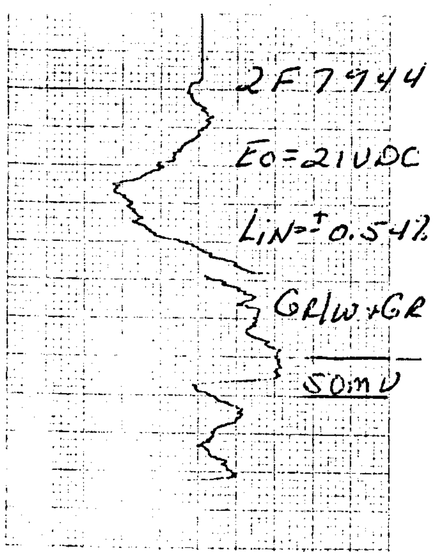
INSULATION RESISTANCE @ 500 VDC = >1000 MEG

RESISTANCE Vio + WH - 20.79 K +0.70K = +3.5%

GR/W + GR - 21.35 K +0.86K = +4.2%

DATE 5-29-63

P.R.O.



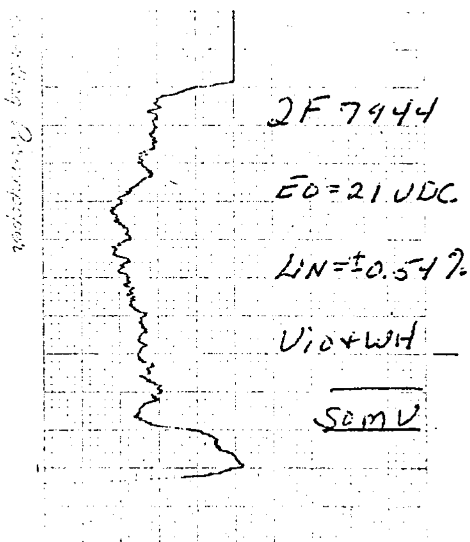


FIGURE 19A

M-113

MARKITE
POTENTIOMETER
PATS. PEND.

TYPE 8598

SER. NO. 3D4444

NOISE OK

LINEARITY SEE TRACE

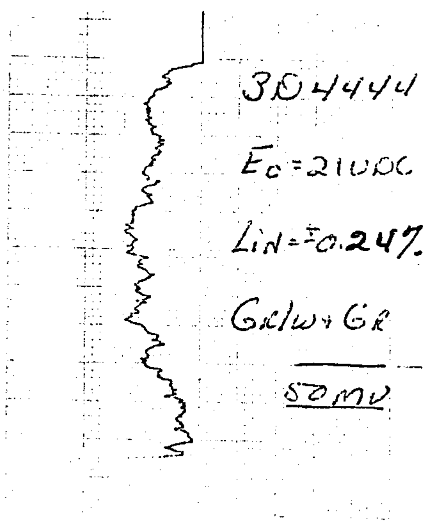
INSULATION RESISTANCE @ 500 VDC = > 1000 MEG

RESISTANCE V10 + WH = 19.20K

GR/W + GR - 19.19K

DATE 5-29-63

P.R.O.



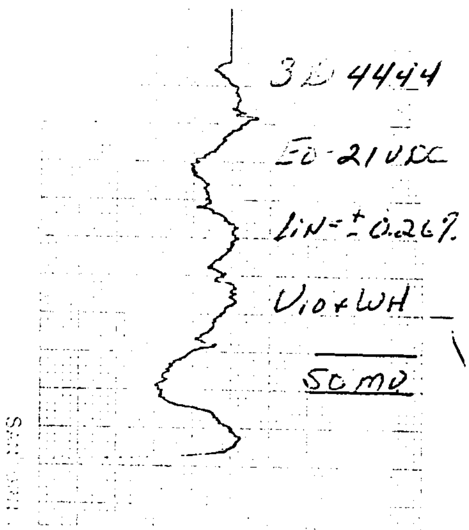


FIGURE 20A

M-118

MARKITE
POTENTIOMETER
PATS. PEND.

TYPE 8598

SER. NO. 3D4200

NOISE (Resistive take off

LINEARITY SEE TRACE

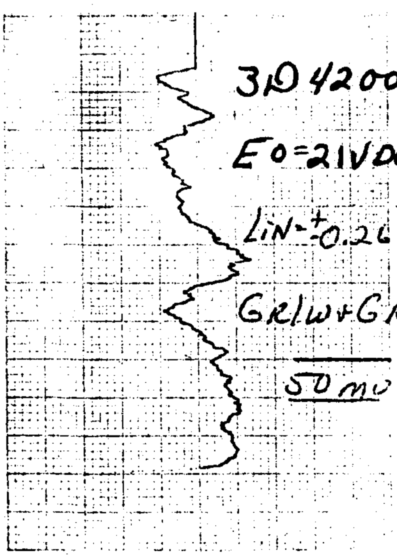
INSULATION RESISTANCE @ 500 VDC = ≥ 1000 MEG

RESISTANCE V10 + WH - 18.09 K

GR/W + GR - 18.36 K

DATE 5-29-63

P.R.O.



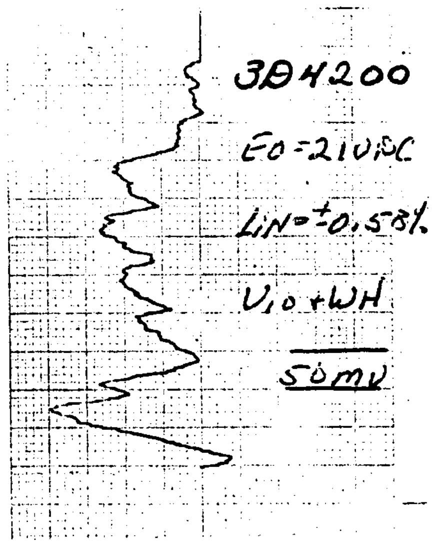


FIGURE 21A

RESEARCH DIVISION
NATIONAL RESEARCH CORPORATION
70 MEMORIAL DRIVE
CAMBRIDGE 42, MASSACHUSETTS

May 6, 1963

Mr. J. J. Riley
Barden Corporation
200 Park Avenue
Danbury, Connecticut

Dear Sir:

COPY

In connection with your telephone conversation with Mr. John Ham of NRC on May 2, 1963, I am forwarding 6 Bartem No. SFR3BS8X112K5 Bearings, Nos. 1 through 6.

Bearings No. 1 and No. 2 were part of Actuator Assembly Serial No. 01 which was operated at room conditions for approximately 10 minutes and then exposed to a vacuum bakeout at 190°F for 8 hours. This was followed by an 8-day soak period at 3×10^{-9} torr. At the conclusion of the 8-day soak period the unit was operated for approximately 30 minutes. The unit was then returned to room conditions and a 5 minute test was performed.

Bearings No. 3 and No. 4 were part of Actuator Assembly Serial No. 02 which were exposed to the same conditions as above except the vacuum test was for 25 hours.

Bearings, No. 5 and No. 6 were statically pre-loaded and exposed to the vacuum conditions listed above. There was no operation performed on these bearings.

This information should assist you in your evaluation of the effects due to vacuum exposure and operation of your bearings. We would appreciate receiving a letter from you stating your findings which will then be incorporated into our report along with our evaluations. If further information is required, please feel free to contact either Mr. John Ham or me here at NRC.

Very truly yours,

Rosario P. Giammanco

RPG:jmc

FIGURE 22A

THE BARDEN CORPORATION BARDEN PRECISION BALL BEARINGS

DANBURY, CONNECTICUT. TELEPHONE: PIONEER 3-9201. TWX: DANB 43

June 20, 1963

Mr. Rosario P. Giammanco
National Research Corporation
70 Memorial Drive
Cambridge 42, Mass.

Dear Mr. Giammanco:

Here is our report on the bearings returned with your letter of May 6, 1963:

Bearing No. 1 - The inner ring of this bearing had multiple brinell marks as a result of excess static or impact thrust load. The inner and outer races showed only very slight indications that this bearing had been run. These indications consisted of very light, uneven deposits of the Bartemp retainer material in the raceway running area. This deposit is considered normal for this type of bearing and provides the necessary lubricant film between balls and races. The balls were clean with no deposit and the retainer had no visible wear.

Bearing No. 2 - Similar to Bearing No. 1, with the exception that there were no brinell marks.

Bearings Nos. 3 and 4 - Slightly heavier deposit of lubricating film on inner and outer races, but otherwise similar to Bearings Nos. 1 and 2.

Bearings Nos. 5 and 6 - In "as new" condition.

It is apparent that the vacuum applied to these bearings did not have an appreciable harmful effect and, in general, the bearings appear as we would expect them to had they been run without exposure to vacuum.

The bearings are being returned to your attention under separate cover.

Very truly yours,
THE BARDEN CORPORATION

L. W. McKee
Chief Product Engineer

65

LWMcK:em

FIGURE 23A

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
54	54	54	54	49.2	24.0	24.6	49.2	24.9	23.9	49	50	51	49
51	51	53	53	49.5	24.4	24.8	49.5	25.0	24.1	49	50	51	49

NO POTENTIOMETER DATA TAKEN DURING BAKEOUT

54	55	55	54	49.1	23.9	24.8	48.9	24.7	24.0	49	51	51	49
54	55	58	54	49.0	23.9	24.6	48.8	24.7	23.8	49	50	51	49
55	58	58	55	49.0	24.1	24.6	48.8	25.0	23.8	49	50	52	49
55	58	58	54	49.0	24.1	24.6	49.0	24.9	23.9	49	50	51	49
55	58	58	53	49.0	24.0	24.6	49.0	24.7	23.8	49	50	51	49

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (1000 ohms) M-N	M-P	N-P	Y-R	Y-Z	R-Z
3/17/63 1700	Read and Outgas	1.7×10^{-9}	45	45	19.0	10.5	11.0	19.0	10.8	10.2
2100	Read and Outgas	1.6×10^{-9}	45	45	19.0	10.5	11.0	19.0	10.9	10.2
3/18/63 0100	Read and Outgas	1.6×10^{-9}	45	45	19.0	10.2	10.8	19.0	10.8	10.1
0500	Read and Outgas	1.7×10^{-9}	45	45	19.0	10.2	10.8	19.0	10.8	10.1
0900	Read and Outgas	1.6×10^{-9}	45	44	19.0	10.4	10.8	19.0	10.8	10.5
1300	Read and Outgas	4.0×10^{-9}	45	45	19.0	10.2	11.0	19.0	10.8	10.5
1700	Read and Outgas	1.5×10^{-9}	45	45	19.0	10.0	10.5	19.0	10.8	10.2
2100	Read and Outgas	1.3×10^{-9}	45	44	19.0	10.0	11.0	19.0	11.0	10.5
3/19/63 0100	Read and Outgas	1.4×10^{-9}	45	45	19.0	10.1	10.5	18.5	10.0	10.0
0500	Read and Outgas	1.3×10^{-9}	45	45	19.0	10.2	10.5	19.0	10.2	10.2
0900	Read and Outgas	1.6×10^{-9}	45	45	19.0	10.5	10.5	19.0	10.5	10.5
1300	Read and Outgas	1.5×10^{-9}	45	45	19.0	10.2	10.3	19.0	10.2	10.3
1700	Read and Outgas	1.2×10^{-9}	45	44	19.0	10.2	10.1	18.8	10.2	10.1
2100	Read and Outgas	1.4×10^{-9}	45	45	19.0	10.2	10.2	19.0	10.2	10.2
3/20/63 0100	Read and Outgas	1.3×10^{-9}	45	45	19.2	10.2	10.2	19.5	10.2	10.2
0500	Read and Outgas	1.2×10^{-9}	45	45	19.0	10.2	10.2	19.0	10.2	10.2
0900	Read and Outgas	1.2×10^{-9}	45	44	19.0	10.2	10.2	19.0	10.2	10.2
1300	Read and Outgas	1.3×10^{-9}	43	44	18.8	10.1	10.2	18.8	10.1	10.2
1700	Read and Outgas	2.0×10^{-9}	43	43	19.0	10.5	10.2	19.0	10.5	10.1
2100	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.5	10.1	19.0	10.4	10.2
3/21/63 0100	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.2	10.2	18.8	10.5	10.5
0500	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.3	10.3	19.0	10.4	10.3
0900	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.2	10.3	18.8	10.4	10.2
1300	Read and Outgas	1.6×10^{-9}	43	43	19.0	10.2	10.3	18.8	10.3	10.2

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
55	58	57	54	49.0	24.3	24.4	48.8	24.6	24.1	49	50	51	50
55	58	58	54	49.0	24.2	24.4	48.9	24.6	24.0	49	50	51	50
54	57	57	53	49.0	24.5	24.3	48.8	24.6	24.0	49	50	51	50
54	57	57	53	48.2	23.5	24.3	48.3	24.2	23.8	49	50	50	49
55	57	57	55	48.2	24.0	24.0	48.2	24.2	23.8	49	50	50	49
54	58	57	55	48.0	23.8	24.0	48.0	24.2	23.5	49	50	50	49
53	55	57	54	48.2	23.8	24.2	48.2	24.3	23.6	49	50	50	49
53	58	58	55	48.0	23.5	24.6	48.0	24.8	23.4	49	51	51	49
53	55	53	53	48.2	23.5	24.5	48.3	24.5	23.5	49	51	51	49
54	55	54	54	48.0	23.5	24.5	48.1	24.3	23.6	49	51	51	49
55	55	54	55	48.0	23.5	24.0	48.0	24.3	23.4	49	50	51	49
54	54	54	54	47.5	23.2	23.8	47.4	23.8	22.9	49	50	50	49
54	53	53	53	47.5	23.2	23.7	47.5	23.7	22.9	49	50	50	49
54	54	54	54	47.6	23.3	24.5	47.6	23.8	24.0	49	51	50	49
54	54	54	54	48.2	23.4	24.4	48.2	24.5	23.3	49	50	51	49
54	54	54	54	48.2	23.3	24.5	48.2	24.4	23.4	49	51	50	49
54	54	54	54	49.9	23.4	24.0	47.9	24.2	23.2	49	50	51	49
53	54	53	54	47.9	23.4	24.0	47.8	24.2	23.3	49	50	51	49
55	54	55	53	48.0	23.5	23.9	48.0	24.2	23.3	49	50	51	49
55	53	54	54	47.8	23.6	23.5	48.0	24.1	23.3	49	49	51	49
54	54	55	55	48.0	23.8	24.0	48.0	24.2	23.6	49	50	51	49
54	54	54	54	48.2	23.4	24.2	48.2	24.2	23.5	49	50	51	49
54	54	54	54	47.8	23.4	23.8	47.8	24.1	23.3	49	50	51	49
54	54	54	54	47.9	23.5	23.9	47.8	24.1	23.3	49	50	51	49

96

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (ohms) M-N	M-P	N-P	Y-R	Y Z	R-Z
3/21/63 1700	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.3	10.4	19.0	10.2	10.3
2100	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.2	10.5	19.0	10.3	10.2
3/22/63 0100	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.2	10.4	19.0	10.3	10.3
0500	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.3	10.3	19.0	10.2	10.3
0900	Read and Outgas	1.4×10^{-9}	43	43	19.0	10.3	10.3	19.0	10.3	10.2
1300	Read and Outgas	1.4×10^{-9}	43	43	18.8	10.2	10.3	19.0	10.3	10.2
1700	Read and Outgas	1.2×10^{-9}	43	43	18.9	10.1	10.4	19.0	10.5	10.2
2100	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.2	10.5	19.1	10.5	10.2
3/23/63 0100	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.3	10.6	19.0	10.5	10.2
0500	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.2	10.6	19.0	10.5	10.2
0900	Read and Outgas	1.4×10^{-9}	43	43	19.1	10.0	10.1	18.6	10.2	10.0
1300	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.2	10.3	18.9	10.2	10.0
1700	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.2	10.4	19.0	10.4	10.1
2100	Read and Outgas	1.2×10^{-9}	44	43	19.0	10.2	10.3	18.8	10.3	10.1
3/24/63 0100	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.3	10.4	18.9	10.2	10.1
0500	Read and Outgas	1.1×10^{-9}	43	43	18.9	10.2	10.5	18.8	10.2	10.0
0900	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.0	10.2	18.2	10.1	10.0
1300	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.1	10.2	18.4	10.0	10.0
1700	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.3	10.2
2100	Read and Outgas	1.3×10^{-9}	43	43	19.0	10.3	10.3	19.0	10.2	10.3
3/25/63 0100	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.2	10.2
0500	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.3	10.2
0900	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.3	10.2

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y Z	R-Z
54	54	54	54	48.1	23.0	24.1	48.1	24.3	23.2	49	50	51	49
54	55	54	54	48.1	23.5	24.0	48.0	24.2	23.3	49	50	51	49
54	54	54	54	48.0	23.5	24.2	48.2	24.1	23.5	49	50	50	49
54	54	54	54	48.1	23.5	24.1	48.1	24.1	23.5	49	50	50	49
54	54	54	54	47.5	23.2	23.7	47.2	23.9	23.0	49	50	51	49
54	54	54	54	47.5	23.3	23.6	47.3	23.9	23.1	49	50	51	49
53	54	55	54	47.7	23.9	24.1	47.4	23.9	23.2	49	50	51	49
54	55	55	54	47.8	23.7	24.0	47.7	24.0	23.3	49	50	51	49
54	55	55	54	47.6	23.6	24.3	47.7	23.9	23.2	49	50	50	49
54	55	55	54	47.7	23.7	24.2	47.6	23.9	23.2	49	50	51	49
53	53	54	53	47.7	23.9	23.9	47.6	23.9	23.8	49	50	51	49
54	54	54	53	47.8	24.0	23.8	48.2	23.9	23.8	49	50	49	49
54	54	54	53	47.9	23.4	24.4	47.9	24.0	23.3	49	50	50	49
54	54	54	53	47.9	23.4	24.0	47.9	24.1	23.2	49	50	51	49
54	54	54	53	47.8	23.6	24.3	47.9	24.0	23.3	49	50	50	49
54	55	54	53	47.8	23.5	24.5	48.3	23.7	23.3	49	50	49	49
53	54	53	53	48.0	23.5	24.4	47.8	24.0	23.7	49	50	51	49
53	54	53	53	48.0	23.5	24.5	47.8	24.0	23.6	49	50	51	49
54	54	54	54	47.9	23.4	24.0	47.9	24.1	23.2	49	50	51	49
54	54	54	54	47.9	23.5	24.0	47.9	24.1	23.3	49	50	51	49
54	54	54	54	47.9	23.5	24.1	47.8	24.0	23.3	49	50	51	49
54	54	54	54	47.9	23.4	24.0	47.9	24.1	23.2	49	50	51	49
54	54	54	54	47.8	23.5	23.9	47.8	24.1	23.2	49	50	51	49

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (1000 ohms) M-N	M-P	N-P	Y-R	Y-Z	R-Z
3/25/63										
0100	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.2	10.2
0500	Read and Outgas	1.1×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.3	10.2
0900	Read and Outgas	1.2×10^{-9}	43	43	19.0	10.2	10.3	19.0	10.3	10.2
0945	Calibrated Test Equipment									
1215	Vacuum Run No. 1 started	1.3×10^{-9}	43	43						
1230	Vacuum Run No. 1 ended	1.3×10^{-9}	43	43						
1300	Read and Outgas	1.2×10^{-9}	43	43	19.2	10.0	9.9	19.3	10.3	10.2
1400	Vacuum Run No. 2 started	1.4×10^{-9}	43	43						
1410	Vacuum Run No. 2 ended	1.4×10^{-9}	44	44						
1450	Special Shutdown procedure started Testing actuator at each pressure decade									
1520	Atmospheric test, dry nitrogen	760	45	45	19.0	10.3	10.2	18.8	10.3	10.1
1640	Atmospheric test, Rear Air									
1700	Torque and equipment calibration check									

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
54	54	54	54	47.9	23.5	24.1	47.8	24.0	23.3	49	50	51	49
54	54	54	54	47.9	23.4	24.0	47.9	24.1	23.2	49	50	51	49
54	54	54	54	47.8	23.5	23.9	47.8	24.1	23.2	49	50	51	49
55	55	55	55	47.5	23.2	23.8	47.5	23.8	23.3	49	50	50	49
54	54	55	54	47.8	23.3	23.8	47.6	24.0	23.2	49	50	51	49

TABLE 3

VACUUM OPERATION, TEST NO. 1, OF

JET VANE ACTUATOR, SERIAL NO. 01 WITH AMPLIFIER NO. 1

March 25, 1963, 1215 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	System Pressure (torr)	Actuator Case Temperature (°F)	Torque Motor Current (milliamps)	Telemetry Potentiometer Noise (millivolts)
0	100 Cycle Noise On Torque Current Signal	±0.2	0.0	1.3×10^{-9}	43	±3.0	0.0
1.0	Torque Current Noise Increasing	±0.6	±0.3	1.3×10^{-9}	43	±5.0	3.0
1.5	Torque Current Noise Still Increasing	±1.2	±0.5	1.3×10^{-9}	43	±6.0	5.0
2.0	Torque Current Noise Still Increasing	±3.0	±1.1	1.3×10^{-9}	43	±5.2	6.0
3.0	Telemetry Potentiometer Noise Increasing	±3.0	±1.1	1.4×10^{-9}	43	Torque Current Not Readable Due To Noise Level	12.0
4.0	Telemetry Potentiometer Noise Still Increasing	±3.0	±1.1	1.4×10^{-9}	43		30.0
4.7	Servo Potentiometer Noise Appearing	±3.9	±1.4	1.5×10^{-9}	43		3.5
5.0	Telemetry Potentiometer Noise Decreasing	±3.9	±1.4	1.7×10^{-9}	43		3.0
6.0	Telemetry Potentiometer Noise Increasing	±4.0	±1.4	1.6×10^{-9}	43		22.0
6.3	Pressure Burst	±4.0	±1.4	1.0×10^{-8}	43		30.0

TABLE 3 (continued)

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	System Pressure (torr)	Actuator Case Temperature (°F)	Torque Motor Current (milliamps)	Telemetry Potentiometer Noise (millivolts)
7.0	Servo Potentiometer Noise Increasing	± 4.0	± 1.5	2.0×10^{-9}	43	Torque Current Not Readable Due To Noise Level	15.0
8.0	Servo Potentiometer Noise Increasing	± 4.0	± 1.5	2.2×10^{-9}	43		15.0
9.0	Servo Potentiometer Noise Decreasing	± 4.0	± 1.5	2.4×10^{-9}	43		10.0
10.0	Servo & Telemetry Potentiometer Noise Increasing	± 4.0	± 1.5	2.0×10^{-9}	43		22.0
11.0	Servo Potentiometer Erratic-- Telemetry Potentiometer Noise Up	± 4.0	± 1.5	2.0×10^{-9}	44		30.0
12.0	"	± 4.0	± 1.5	1.3×10^{-9}	44		30.0
13.0	"	± 4.0	± 1.5	1.4×10^{-9}	44		30.0
13.75	End of Run Servo Potentiometer Still Erratic	± 4.0	± 1.5	1.3×10^{-9}	44		30.0

TABLE 4

VACUUM OPERATION, TEST NO. 2, OF JET VANE ACTUATOR

SERIAL NO. 01 WITH AMPLIFIER NO. 1

March 25, 1963, 1400 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	System Pressure (torr)	Actuator Case Temperature (°F)	Torque Motor Current (milliamps)	Telemetry Potentiometer Noise (millivolts)
0		±0.15	0.0	1.4×10^{-9}	43	± 1.5	0.0
1.0	Torque Current Signal 100 Cycle Noise Decreased	±4.0	±1.4	1.4×10^{-9}	43	±15.0	6.0
2.0	Torque Current Signal Increased	±4.0	±1.4	2.0×10^{-9}	43	---	15.0
3.0	Servo Potentiometer Noise Appearing	±4.0	±1.4	2.8×10^{-9}	43	---	8.0
3.5	Pressure Burst	±4.0	±1.4	3.0×10^{-8}	43	---	10.0
4.0	Servo Potentiometer Signal Very Erratic, Telemetry Potentiometer Signal Also Erratic	±4.0	±1.4	2.2×10^{-9}	44	---	30.0
5.0	"	±4.0	±1.4	2.2×10^{-9}	44	---	8.0
6.0	"	±4.0	±1.4	2.4×10^{-9}	44	---	8.0
7.0	"	±4.0	±1.4	2.2×10^{-9}	44	---	30.0
8.0	"	±4.0	±1.4	2.2×10^{-9}	44	---	75.0
9.0	"	±4.0	±1.4	2.2×10^{-9}	44	---	20.0
10.0	End of Test Run	±7.0	±1.4	2.3×10^{-9}	45	±45	30.0

TABLE 5

VENTING OPERATION TEST OF JET VANE ACTUATOR

SERIAL NO. 01 WITH AMPLIFIER NO. 1

March 25, 1963, 1450 Hours

Operation Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	System Pressure (torr)	Actuator Case Temperature (°F)	Torque Motor Current (milliamps)	Telemetry Potentiometer Noise (millivolts)
1	Servo Potentiometer Voltage Noisy	±2.4	±0.8	7.0×10^{-9}	45	Signal Not Readable Due To Noise Level	3.0
1	"	±2.4	±0.8	5.0×10^{-8}	45		5.0
1	"	±2.4	±0.8	5.0×10^{-7}	44		30.0
1	"	±2.4	±0.8	5.0×10^{-6}	44		6.0
1	Actuator Zero Position Shifted	±2.4	±0.8	4.0×10^{-5}	43		6.0
1	Adjusted Amplifier Balance Potentiometer	±1.1	±0.3	---	43		5.0
3	Servo Potentiometer Voltage Clearing Up	±3.1	±1.1	760	43		10.0

TABLE 6

POST VACUUM ATMOSPHERIC TEST

OF JET VANE ACTUATOR

SERIAL NO. 01 WITH AMPLIFIER NO. 1

March 25, 1963, 1640 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	System Pressure (torr)	Actuator Case Temperature (°F)	Torque Motor Current (milliamps)	Telemetry Potentiometer Noise (millivolts)
0	Torque Current Very Noisy	±0.3	±0.1	760	78	Signal Not Readable Due to Noise Level	0.5
1		±3.8	±1.4	760	78		3.5
1.5		±3.8	±1.4	760	78		4.0

TABLE 7

CALIBRATION OF JET VANE ACTUATOR

SERIAL NO. 01 WITH AMPLIFIER NO. 1 (Torque Vs Current)

Date	Remarks	Weight (grams)	Torque (oz-in)	Current (milliamps) Clockwise	Current (milliamps) Counter Clockwise
3/15/63	Before Vacuum Exposure	10	0.09	4.1	4.1
		20	0.18	7.3	7.3
		50	0.44	15.5	15.0
		100	0.89	30.0	30.0
		150	1.33	42.5	42.5
		200	1.78	56.0	56.0
		250	2.22	70.0	70.0
		300	2.66	83.0	*
3/25/63	After Vacuum Exposure	50	0.44	14.0	12.0
		100	0.89	26.5	23.0
		200	1.78	49.0	46.0

*Torque motor stalls with > 2.20 oz.-in. °F -- Torque in Counter Clockwise direction.

TABLE 8

CALIBRATION FACTORS OF MULTI-CHANNEL RECORDER

FOR JET VANE ACTUATOR, SERIAL NO. 01 WITH AMPLIFIER NO. 1

Recorder Channel	Parameter Measured	Calibration Factor
1	Input Voltage	3 volts/cm
2	Servo Potentiometer Output Voltage	3 volts/cm
3	Vacuum System Pressure	4 millivolts/cm on $\frac{1}{1}$ scale
4	Actuator Case Temperature	2 millivolts/cm on $\frac{1}{1}$ scale
5	Torque Current	15 milliamps/cm
6	Telemetry Potentiometer Noise	30 millivolts/cm

TABLE 9

PRE-VACUUM ATMOSPHERIC TEST NO. 1 OF

JET VANE ACTUATOR, SERIAL NO. 02 WITH AMPLIFIER NO. 4

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
		April 5, 1963 1545 Hours					
0	Telemetry Potentiometer Noise Slightly Erratic	±2.7	±0.9	0.0	760	± 9.0	±0.8
1.0	"	±2.7	±1.0	1.5	760	±14.0	±0.8
2.0	"	±2.7	±1.0	3.8	760	±15.0	±0.8
3.0	"	±3.5	±1.2	6.4	760	±16.5	±1.0
4.0	"	±3.0	±1.1	4.5	760	±16.5	±1.0
5.0	"	±3.0	±1.1	3.8	760	±16.5	±1.0
6.0	"	±3.0	±1.1	3.8	760	±17.4	±1.0
		April 8, 1963, 1645 Hours					
0	"	±3.0	±1.1	0.0	760	±10.5	±1.0
1.0	"	±3.0	±1.1	6.0	760	±15.0	±1.0
2.0	"	±3.0	±1.1	6.0	760	±16.5	±1.0
3.0	"	±3.0	±1.1	6.2	760	±16.5	±1.0
4.0	"	±3.0	±1.1	6.0	760	±16.5	±1.0

TABLE 9 (continued)

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
		April 8, 1963, 1645 Hours					
5.0	Telemetry Potentiometer Noise Slightly Erratic	±3.0	±1.1	6.0	760	±16.5	±1.0
6.0	"	±3.0	±1.1	5.8	760	±16.5	±1.0
7.0	"	±3.0	±1.1	5.6	760	±16.5	±1.0
8.0	"	±3.0	±1.1	5.8	760	±16.5	±1.0
9.0	"	±3.0	±1.1	5.8	760	±16.0	±1.0
10.0	"	±3.0	±1.1	5.8	760	±16.0	±1.0
11.0	"	±3.0	±1.1	5.8	760	±16.0	±1.0
12.0	"	±3.0	±1.1	6.0	760	±16.0	±1.0
		April 9, 1963, 1335 Hours					
0	"	±3.75	±1.2	1.5	760	±14.0	±1.1
1.0	"	±3.41	±1.1	1.5	760	±14.0	±1.0
2.0	"	±4.2	± 1.5	8.0	760	±15.0	±1.4
2.5	"	±4.2	±1.5	10.0	760	±15.0	±1.4

TABLE 10

PRE-VACUUM ATMOSPHERIC TEST NO. 2

OF JET VANE ACTUATOR, SERIAL NO. 02 WITH AMPLIFIER NO. 4

April 9, 1963, 1400 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
0	100 Cycle Noise On Torque Current	±1.2	±0.5	6.0	760	±14.0	±0.3
1.0	Transistor Trouble Replaced Transistor To Get Best Signal	±2.1	±0.8	4.0	760	±16.5	±0.6
2.0	"	±2.1	±0.8	2.0	760	±16.5	±0.6
3.0	"	±2.1	±0.8	2.0	760	±16.5	±0.6
4.0	"	±2.4	±0.8	4.0	760	±16.5	±0.6
5.0	"	±2.4	±0.8	4.0	760	±16.5	±0.6
6.0	"	±2.4	±0.8	4.0	760	±15.0	±0.6
7.0	"	±1.8	±0.6	3.0	760	±16.0	±0.5
8.0	"	±1.5	±0.6	7.5	760	±15.0	±0.5
9.0	"	±2.1	±0.6	3.8	760	±15.0	±0.5
10.0	"	±1.9	±0.6	3.8	760	±15.0	±0.5
11.0	"	±1.9	±0.6	7.5	760	±15.0	±0.5
12.0	"	±1.9	±0.6	7.5	760	±15.0	±0.5

TABLE 10 (continued)

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
13.0	All Circuits Operating Normal	±1.9	±0.6	7.5	760	±15.0	±0.5
14.0	"	±1.6	±0.5	7.5	760	±15.0	±0.5
15.0	End of Test Run	±1.7	±0.6	7.5	760	±15.0	±0.5

///

TABLE 11

LOG OF VACUUM SYSTEM PRESSURE AND OF THE PRESSURE

INSIDE THE JET VANE ACTUATOR CASE (SERIAL NO. 02)

DURING INITIAL PUMPDOWN AND VENTING PHASES OF EXPOSURE TEST NO. 2

Date/Time	Remarks	Manometer Readings Left (mm)	Manometer Readings Right (mm)	Actuator Pressure (torr)	System Pressure (torr)
4/9/63 1452	Pumpdown Started	458	458	749	749
1453	Read	446	470	725	700
1454	Read	396	520	625	610
1456	Read	361	575	535	530
1500	Read	275	640	384	380
1506	Read	194	720	213	210
1511	Read	152	760	141	140
1515	Read	131	781	99	93
1520	Read	114	798	65	58
1525	Read	91	821	19	13.5
1530	Read	84	827	6	3.3
1540	Read	82	829	2	9.2×10^{-3}
1550	Closed Manometer Clamp	82	829	2	5.2×10^{-3}
4/19/63 1231	Opened Manometer Clamp -- Venting with Dry Nitrogen	823	89	16	28
1232	Read	810	105	35	50
1233	Read	765	155	140	180
1234	Read	655	265	360	400
1235	Read	590	330	490	510
1236	Read	550	370	570	600

TABLE 11 (continued)

Date/Time	Remarks	Manometer Readings Left (mm)	Manometer Readings Right (mm)	Actuator Pressure (torr)	System Pressure (torr)
4/19/63 1237	Read	485	435	700	710
1238	Read -- System at atmosphere	458	458	750	750

TABLE 12

LOG OF PUMPDOWN DATA AND POTENTIOMETER DATA

FOR EXPOSURE TEST No. 2

(JET VANE ACTUATOR, SERIAL NO. 02 POTENTIOMETER, SERIAL NO. 200)
AND PRE-LOADED BEARING

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (1000 ohms) M-N	M-P	N-P	Y-R	Y-Z	R-Z
4/8/63 1700	Read - after conditioning of potentiometer	760	75	75	19.0	9.8	10.0	18.9	10.2	10.1
4/9/63 1200	Read - after installation of potentiometer	760	79	79	18.5	10.0	10.1	19.0	10.2	10.0
1230	Torque and equipment calibrated	760	81	81						
1400	Run Atmospheric Pre-Vacuum Test	760	81	81						
1452	Mechanical Pump on (See Table 11 for manometer data)	760	82	82						
1625	2" Diffusion Pump On	4.5×10^{-3}	81.5	81						
1855	6" Diffusion Pump On	4.3×10^{-5}	73	74	17.9	9.5	9.9	18.1	10.1	10.0
1900	Bakeout started, liquid nitrogen to rear trap	4.0×10^{-5}	73	74						
2200	Read	1.5×10^{-5}	158	185	18.1	9.9	10.1	17.9	10.0	9.9
4/10/63 0200	Read	1.0×10^{-5}	161	186	18.2	9.9	10.1	18.0	10.1	9.9
0600	Bakeout ended, liquid nitrogen to front trap	9.5×10^{-6}								
0630	Read and Outgas	1.2×10^{-6}								
1000	Read and Outgas	1.3×10^{-8}	47	44	19.0	10.0	10.1	18.0	10.1	10.0
1400	Read and Outgas	1.0×10^{-8}	45	42	18.5	10.0	10.0	18.0	10.0	10.0
1800	Read and Outgas	9.6×10^{-9}	45	42	18.4	9.7	10.0	18.1	9.8	9.7
2200	Read and Outgas	8.2×10^{-9}	46	42	18.2	9.8	10.0	18.0	9.9	9.9
4/11/63 0200	Read and Outgas	7.2×10^{-9}	45	42	18.1	9.8	10.0	18.0	9.9	9.9
0600	Read and Outgas	6.2×10^{-9}	44	42	18.0	9.8	10.0	18.0	9.9	9.8
1000	Read and Outgas	6.3×10^{-9}	45	42	18.2	9.8	10.0	17.9	10.0	9.8
1400	Read and Outgas	7.7×10^{-9}	44	40	18.5	10.0	10.1	18.0	10.0	9.9
1800	Read and Outgas	6.6×10^{-9}	45	42	18.1	9.7	10.0	18.0	9.8	9.8

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
52	53	54	53	47.5	22.9	23.8	47.4	23.8	23.2	48	50	50	48
53	53	54	53	48.2	23.2	24.5	48.0	24.0	24.0	48	51	50	50
53	55	56	56	48.1	23.1	24.3	48.1	24.1	23.4	48	51	50	48
55	56	56	55	48.2	23.3	24.4	48.1	24.2	23.4	48	51	50	48
55	56	56	55	48.5	23.2	24.6	48.5	24.2	23.5	48	51	50	48
54	54	55	55	48.4	23.5	24.6	48.3	24.4	23.7	48	51	51	49
55	55	55	55	48.4	23.5	24.6	48.2	24.4	23.7	48	51	51	49
54	55	54	54	48.2	24.0	24.3	48.5	24.2	23.5	49	51	50	48
54	55	54	54	48.2	23.9	24.1	48.3	24.2	23.7	49	50	51	49
54	55	54	54	48.0	23.2	24.2	48.0	24.1	23.5	48	51	50	48
54	55	54	54	47.9	23.1	24.2	47.9	24.0	23.2	48	51	50	48
54	55	55	54	47.9	23.2	24.1	48.0	24.1	23.3	48	51	50	48
55	55	55	54	47.9	23.8	24.3	47.9	24.2	23.5	48	51	51	48
54	55	54	54	48.2	23.6	24.3	48.2	24.3	23.5	48	51	51	48

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (1000 ohms) M-N	M-P	N-P	Y-R	Y-Z	R-Z
4/11/63										
2200	Read and Outgas	6.1×10^{-9}	45	42	18.0	9.7	10.0	17.9	9.9	9.7
4/12/63										
0200	Read and Outgas	5.9×10^{-9}	45	42	18.1	9.9	10.0	18.1	10.0	9.8
0600	Read and Outgas	5.4×10^{-9}	45	42	17.9	9.8	9.9	17.9	9.9	9.8
1000	Read and Outgas	6.2×10^{-9}	45	42	18.0	9.9	9.9	18.0	10.0	9.8
1400	Read and Outgas	6.9×10^{-9}	45	42	18.2	9.9	9.9	18.0	10.0	9.8
1800	Read and Outgas	5.0×10^{-9}	45	42	18.0	9.8	10.0	17.8	9.9	9.8
2200	Read and Outgas	4.9×10^{-9}	45	42	18.1	9.8	10.0	18.0	10.0	9.8
4/13/63										
0200	Read and Outgas	4.9×10^{-9}	45	42	18.0	9.8	10.0	17.9	9.9	10.0
0600	Read and Outgas	5.0×10^{-9}	45	42	18.0	9.9	10.0	18.0	10.0	9.9
1000	Read and Outgas	5.8×10^{-9}	45	42	18.0	9.9	10.0	18.0	10.0	9.9
1400	Read and Outgas	5.5×10^{-9}	45	42	18.0	10.0	10.0	18.0	10.0	10.0
1800	Read and Outgas	4.7×10^{-9}	45	42	18.2	9.9	10.0	18.0	10.1	9.9
2200	Read and Outgas	4.8×10^{-9}	45	42	18.2	9.8	10.0	18.0	10.0	9.8
4/14/63										
0200	Read and Outgas	4.9×10^{-9}	45	42	18.0	9.9	10.0	17.9	9.9	9.8
0600	Read and Outgas	5.0×10^{-9}	45	42	18.0	9.8	10.0	17.9	10.0	9.9
1000	Read and Outgas	4.9×10^{-9}	45	42	17.9	9.8	9.9	17.9	9.9	9.8
1400	Read and Outgas	4.6×10^{-9}	45	42	17.9	9.7	9.9	17.8	9.9	9.7
1800	Read and Outgas	4.6×10^{-9}	45	42	17.9	9.8	10.0	17.9	9.9	9.8
2200	Read and Outgas	4.5×10^{-9}	45	42	17.9	9.7	10.0	17.8	9.9	9.8
4/15/63										
0200	Read and Outgas	3.8×10^{-9}	45	42	18.0	9.8	10.0	18.0	10.0	9.8
0600	Read and Outgas	4.1×10^{-9}	45	42	18.0	9.8	9.9	18.0	9.9	9.8
1000	Read and Outgas	4.1×10^{-9}	45	42	18.3	10.2	10.1	18.2	10.1	10.0
1400	Read and Outgas	4.2×10^{-9}	46	42	18.1	10.1	10.0	18.2	10.0	10.1
1800	Read and Outgas	4.0×10^{-9}	47	43	17.9	9.8	9.9	18.0	9.9	9.8
2200	Read and Outgas	4.0×10^{-9}	47	42	18.1	9.8	9.9	18.2	9.8	9.7

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
54	55	54	54	48.3	23.5	24.4	48.2	24.3	23.6	48	51	51	49
54	55	55	54	48.1	23.2	24.3	48.0	24.1	23.3	48	51	50	48
54	54	54	54	48.1	23.2	24.4	48.1	24.1	23.4	48	51	50	48
54	54	55	54	48.0	23.5	24.4	48.0	24.2	23.6	48	51	51	49
54	54	55	54	48.0	22.3	24.7	48.0	24.4	23.5	48	52	51	49
54	55	54	54	47.9	23.1	24.9	47.8	24.0	23.8	48	52	51	49
54	55	55	54	47.9	23.2	24.3	47.8	24.2	23.5	48	51	51	49
54	55	54	55	48.2	23.5	24.5	48.2	24.2	23.6	48	51	51	48
54	55	55	54	48.1	23.5	24.5	48.2	24.2	23.5	48	51	50	48
54	55	55	54	48.0	23.3	24.4	48.4	24.0	23.5	48	51	49	48
54	55	55	55	48.2	23.5	24.4	48.4	24.0	23.4	48	51	49	48
54	55	55	54	48.2	23.3	24.3	47.8	24.2	23.3	48	51	51	48
54	55	55	54	48.2	23.4	24.3	48.0	24.2	23.5	48	51	51	48
54	55	55	54	48.2	23.4	24.5	48.2	24.2	23.5	48	51	51	48
54	55	55	54	48.2	23.4	24.5	48.2	24.2	23.5	48	51	50	48
54	54	54	54	48.2	23.3	24.4	48.1	24.1	23.4	48	51	50	48
54	54	54	54	47.9	23.2	24.2	48.0	24.0	23.3	48	51	50	48
54	54	54	54	47.8	23.1	24.4	48.2	24.2	23.4	48	51	50	48
54	54	54	54	47.8	23.1	24.3	48.1	24.2	23.4	48	51	50	48
54	55	55	54	48.2	23.2	24.2	48.2	24.2	23.5	48	50	50	48
54	54	54	54	48.2	23.2	24.2	48.2	24.2	23.5	49	50	50	48
56	55	55	55	47.8	23.5	24.2	47.8	24.2	23.4	48	51	51	48
55	55	55	55	47.5	23.0	24.5	47.5	23.9	23.2	48	51	50	48
54	54	54	54	47.5	22.9	23.9	47.6	23.9	23.0	48	51	50	48
54	54	54	54	47.7	23.0	24.1	47.5	23.9	23.2	48	51	50	48

118

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	M-N	Potentiometer Resistance (1000 ohms) M-P	N-P	Y-R	Y-Z	R-Z
4/16/63 0200	Read and Outgas	3.9×10^{-9}	47	42	17.9	9.8	10.0	17.9	9.9	9.8
0600	Read and Outgas	3.9×10^{-9}	47	42	17.9	9.9	10.0	17.9	9.9	9.9
1000	Read and Outgas	4.6×10^{-9}	48	43	18.0	9.6	10.0	17.8	9.8	9.5
1400	Read and Outgas	4.7×10^{-9}	48	43	18.0	9.6	10.0	17.7	9.8	9.6
1800	Read and Outgas	4.5×10^{-9}	49	44	17.9	9.8	10.0	17.9	10.0	9.8
2200	Read and Outgas	4.1×10^{-9}	50	44	17.9	9.8	10.0	17.9	9.9	9.8
4/17/63 0200	Read and Outgas	4.3×10^{-9}	50	43	17.9	9.8	10.0	18.0	10.0	9.8
0600	Read and Outgas	4.4×10^{-9}	50	43	18.0	9.8	9.9	17.9	10.0	9.8
1000	Read and Outgas	4.4×10^{-9}	48	42	18.0	9.5	10.0	17.8	10.0	9.5
1400	Read and Outgas	4.4×10^{-9}	48	42	18.0	9.6	10.0	17.8	10.0	9.6
1800	Read and Outgas	4.2×10^{-9}	48	42	18.0	9.8	10.0	17.8	10.0	9.8
2200	Read and Outgas	3.9×10^{-9}	48	42	18.0	9.8	10.0	17.8	10.0	9.7
4/18/63 0200	Read and Outgas	4.2×10^{-9}	48	42	18.0	9.8	10.0	18.0	10.0	9.8
0600	Read and Outgas	3.9×10^{-9}	48	42	18.0	9.8	10.0	18.0	10.0	9.8
0915	Instrumentation calibrated	4.2×10^{-9}	48	42						
1000	Read and Outgas	4.6×10^{-9}	48	42	18.0	9.8	9.9	18.0	9.9	9.6
1015	Actuator vacuum test started	5.6×10^{-9}	48	42						
1200	Read -- Taking actuator data every 5 minutes	5.1×10^{-9}	50	42	18.2	9.6	10.0	18.1	10.0	9.8
1530	Actuator shifted -- Readjusted balance to stop shift of zero point	6.3×10^{-9}	50	42						
1700	Read -- Taking actuator data every 15 minutes	6.5×10^{-9}	51	43	18.2	9.8	10.0	18.1	10.0	9.8
1900	UHV gauge kicking off due to pressure burst									

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M-N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
54	54	54	54	48.1	23.2	24.2	48.1	24.2	23.3	48	51	50	48
54	54	54	54	48.1	23.2	24.2	48.1	24.1	23.2	48	51	50	48
53	54	54	53	47.7	23.0	24.2	47.6	23.9	23.3	48	51	50	48
53	54	54	53	47.8	23.1	24.1	47.8	23.8	23.2	48	51	50	48
54	55	55	54	48.0	23.0	24.2	48.0	24.0	23.3	48	51	50	48
54	54	54	54	48.0	23.1	24.2	48.0	23.9	23.3	48	50	50	48
54	55	55	54	48.1	23.2	24.2	48.1	24.2	23.3	48	50	50	48
54	55	55	54	48.1	23.2	24.2	48.1	24.2	23.3	48	51	50	48
53	55	55	53	47.8	23.1	24.1	47.8	24.1	23.2	48	51	50	48
53	55	55	53	47.7	23.1	24.2	47.8	24.2	23.2	48	51	51	48
54	55	55	54	47.8	23.3	24.1	47.9	24.0	23.3	48	51	51	48
54	55	55	54	47.8	23.2	24.1	47.9	24.2	23.3	48	51	50	48
54	55	55	54	48.1	23.2	24.2	48.1	24.2	23.3	48	51	51	48
54	55	55	54	48.1	23.2	24.2	48.1	24.2	23.3	48	51	50	48
54	54	54	53	47.8	23.1	24.2	47.8	24.0	23.4	48	51	50	48
53	55	55	54	47.8	23.2	24.1	47.9	24.0	23.3	48	51	50	48
53	55	55	54	47.8	23.2	24.1	47.9	24.0	23.3	48	51	50	48

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (1000 ohms) M-N	M-P	N-P	Y-R	Y-Z	R-Z
4/18/63 2100	Read	6.5×10^{-9}	48	44	18.2	9.9	10.0	18.0	10.0	9.9
4/19/63 0100	Read	6.6×10^{-9}	49	44	18.1	9.9	10.0	17.9	10.0	9.8
0500	Read	6.8×10^{-9}	50	43	18.2	9.9	10.0	17.9	10.0	9.9
0900	Read	6.8×10^{-9}	49	42	18.0	9.5	10.0	18.0	10.0	9.6
1050	Read	6.8×10^{-9}	50	43	18.0	9.8	10.0	18.0	10.0	9.8
1100	Special shutdown procedure started -- Actuator still operating Taking data at each pressure level									
1230	Venting with dry nitrogen	28								
1238	Actuator still operating but deteriorating fast	750								
1240	Actuator test ended	750	58	45	18.0	9.7	10.0	18.2	10.0	9.7
1245	Read	750	50	52						

% of Total Resistance				Potentiometer Voltage (volts)						% of Total Voltage			
M-P	N-P	Y-Z	R-Z	M N	M-P	N-P	Y-R	Y-Z	R-Z	M-P	N-P	Y-Z	R-Z
54	55	55	54	48.0	23.3	24.3	47.8	24.1	23.3	48	51	51	48
54	55	55	54	47.9	23.2	24.2	47.8	24.1	23.2	48	51	51	48
54	55	55	54	47.9	23.2	24.2	47.8	24.0	23.2	48	51	50	48
53	55	55	53	48.0	23.2	24.2	47.8	24.0	23.2	48	51	50	48
54	55	55	54	48.0	23.0	24.1	47.7	24.1	23.3	47	51	51	48
54	55	55	54	47.9	20.2	24.2	47.9	24.1	23.3	48	51	50	48

TABLE 13

VACUUM OPERATION TEST

OF JET VANE ACTUATOR, SERIAL NO. 02 WITH AMPLIFIER NO. 4

April 18, 1963, 1015 Hours

Elapsed Time (Hours)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
0	All Signals Normal	±0.3	0.0	0.0	5.6×10^{-9}	± 3.0	0.0
0.5	"	±2.1	±0.6	3.7	5.0×10^{-9}	±27.0	±0.9
1.0	"	±2.1	±0.6	3.0	5.2×10^{-9}	±23.5	±0.8
1.5	"	±2.0	±0.6	3.0	5.6×10^{-9}	±23.0	±0.8
2.0	"	±2.1	±0.6	3.2	5.6×10^{-9}	±22.5	±0.8
3.0	"	±2.1	±0.6	3.0	5.9×10^{-9}	±22.5	±0.8
4.0	"	±1.8	±0.6	2.4	6.2×10^{-9}	±21.0	±0.8
5.0	"	±1.8	±0.6	10.0	6.2×10^{-9}	±22.5	±0.8
5.1	Actuator Zero Position Shifted	±2.1	±0.3	7.5	6.2×10^{-9}	±22.0	±0.8
5.2	Reduced Input Voltage	±0.8	±0.2	1.2	5.9×10^{-9}	±22.0	±0.5
5.3	Shifted Zero Balance Potentiometer	±1.8	±0.5	5.4	6.0×10^{-9}	±22.5	±0.8
5.4	All Signals Normal Again	±1.8	±0.5	5.0	6.0×10^{-9}	±22.5	±0.8
6.0	All Signals Normal	±2.3	±0.8	4.3	6.0×10^{-9}	±22.5	±0.8

TABLE 13 (continued)

Elapsed Time (Hours)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
7.0	All Signals Normal	±2.3	±0.8	5.8	6.1×10^{-9}	±23.1	±0.8
8.0	"	±2.3	±0.8	4.1	6.1×10^{-9}	±22.6	±0.8
9.0	"	±2.3	±0.8	4.0	5.9×10^{-9}	±22.8	±0.8
10.0	"	±2.3	±0.8	7.8	5.8×10^{-9}	±22.5	±0.8
11.0	"	±2.3	±0.8	6.2	5.1×10^{-9}		±0.8
12.0	"	±2.2	±0.8	4.0	4.5×10^{-9}		±0.8
13.0	"	±2.2	±0.8	3.8	4.0×10^{-9}		±0.8
14.0	"	±2.2	±0.8	3.8	4.0×10^{-9}		±0.8
15.0	"	±2.2	±0.8	3.7	4.0×10^{-9}		±0.8
16.0	Pressure Burst	±2.2	±0.8	11.5	6.6×10^{-7}		±0.8
17.0	All Signals Normal	±2.2	±0.8	7.5	6.3×10^{-9}		±0.8
18.0	"	±2.0	±0.8	5.2	5.9×10^{-9}		±0.7
19.0	Pressure Burst	±2.0	±0.8	7.8	1.0×10^{-8}		±0.7
20.0	All Signals Normal	±2.0	±0.8	4.0	6.8×10^{-9}		±0.8
21.0	"	±2.0	±0.8	4.0	6.8×10^{-9}		±0.8
22.0	"	±2.0	±0.8	4.0	7.0×10^{-9}		±0.6
23.0	"	±2.0	±0.7	4.0	7.2×10^{-9}		±0.6
24.0	"	±2.0	±0.6	3.7	7.0×10^{-9}		±0.5

TABLE 14

VENTING OPERATION TEST OF

JET VANE ACTUATOR, SERIAL NO. 02 WITH AMPLIFIER NO. 4

April 19, 1963, 1100 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
0	All Channels Operating Normally	±2.4	±0.8	4.5	7.0×10^{-9}	±22.5	±0.8
Total Venting Time -- 98 minutes	Torque Current and Telemetry Potentiometer Noise Signals Increasing With Pressure	±2.1	±0.7	4.6	2.0×10^{-8}	±22.5	±0.7
		±2.1	±0.7	4.5	4.0×10^{-8}	±22.5	±0.7
		±2.1	±0.7	6.0	6.0×10^{-8}	±22.5	±0.7
		±2.1	±0.7	5.4	8.0×10^{-8}	±22.5	±0.7
		±2.1	±0.7	5.4	1.0×10^{-7}	±22.5	±0.7
		±1.8	±0.7	3.7	5.0×10^{-7}	±21.5	±0.7
		±1.9	±0.7	4.0	5.0×10^{-6}	±19.0	±0.7
		±2.1	±0.7	7.5	5.0×10^{-5}	±22.5	±0.7
		±2.1	±0.7	7.5	1.6×10^{-4}	±22.5	±0.7
		±2.1	±0.7	7.6	---	±21.5	±0.7
	Torque Current Signal Not Readable	±2.1	±0.7	15.0	28	Torque Current Not Readable Due To Noise Level	±0.7
	Opened Manometer Clamp	±2.1	±0.7	11.8	280		±0.7
	Torque Current Noise Still Increasing	±2.1	±0.7	15.0	180		±0.8

TABLE 14 (continued)

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
Total Venting Time 98 minutes	Torque Current Noise Still Increasing	±2.1	±0.7	15.0	400	Torque Current Not Readable Due To Noise Level	±0.8
		±2.1	±0.7	15.0	600		±0.8
		±2.1	±0.7	11.2	760		±0.8

TABLE 15

POST VACUUM ATMOSPHERIC TEST

OF JET VANE ACTUATOR, SERIAL NO. 02 WITH AMPLIFIER NO. 4

April 19, 1963, 1238 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	Telemetry Potentiometer Noise (millivolts)	System Pressure (torr)	Torque Motor Current (milliamps)	Telemetry Potentiometer Voltage (volts)
0	Torque Current Noise Level Very High	±2.1	±0.7	11.2	760		±0.8
1.0	"	±2.1	±0.7	11.2	760	Noise Level At Highest Level	±0.8
1.5	"	±2.1	±0.7	11.2	760		±0.8

TABLE 16

CALIBRATION OF JET VANE ACTUATOR

SERIAL NO. 02 WITH AMPLIFIER NO. 4 (Torque Vs. Current)

Date	Remarks	Weight (grams)	Torque (oz-in)	Current (milliamps) Clockwise	Current (milliamps) Counter Clockwise
4/8/63	Before Vacuum Exposure	20	0.18	8.0	10.0
		50	0.44	18.5	19.0
		100	0.89	37.0	33.5
		150	1.33	52.0	47.0
		200	1.78	67.0	62.0
		220	1.96	77.0	68.0
4/19/63	After Vacuum Exposure*	20	0.18	7.0	9.0
		50	0.44	17.0	21.0
		100	0.89	33.0	32.0
		150	1.33	55.0	46.0
		200	1.78	76.0	61.0
		220	1.96	**	68.0
		250	2.22		74.0

*Torque Motor Balance Changed During Vacuum Test and Had To Be Shifted Which Changes Calibration

**Torque Motor Stalls With > 1.78 oz.-in. of Torque in Clockwise Direction

TABLE 17

CALIBRATION FACTORS OF MULTI-CHANNEL RECORDER

FOR JET VANE ACTUATOR, SERIAL NO. 02 WITH AMPLIFIER NO. 4

Recorder Channel	Parameter Measured	Calibration Factor
1	Input Voltage	3 volts/cm
2	Servo Potentiometer Output Voltage	3 volts/cm
3	Telemetry Potentiometer Noise	30 millivolts/cm on $\frac{1}{8}$ scale
4	Vacuum System Pressure	4 millivolts/cm on $\frac{1}{1}$ scale
5	Torque Current	15 milliamps/cm
6	Telemetry Potentiometer Output Voltage	3 volts/cm

APPENDIX B

GAS ESCAPE RATE FROM JET VANE ACTUATOR ASSEMBLY IN VACUUM

The jet actuators were mounted inside an evacuated chamber which was then pumped down and held under vacuum for eight days. One of the two actuators (unit No. 02) was tested with its cover plate in place but with no "O" rings around its shaft so that all of the air initially inside had to come out through two very narrow (0.002") annular spaces as shown in Fig. 1B.

It was assumed that substantially all of the air would be removed in a very short time compared to the eight day holding period so that any gas escaping during operation of the device at the end of this period could represent only surface desorption from the internal parts of the device. The following calculations confirm this assumption.

The notation and formulae used are from S. Dushman "Vacuum Technique", John Wiley, 1949. On page 102 Dushman gives the formula ($F_o = 75.3\ A_i$ 1/sec) used below for the conductance of an orifice for air at 25°C. Since the formula $F_m = .0583\ P_{mm} \sqrt{\frac{M}{T}}$ which he gives on page 17 is more basic and probably more familiar, the derivation of the formula used is given here.

$$\text{Mass Flux (orifice)} = F_m = .0583\ P_{mm} \sqrt{\frac{M}{T}} \quad \text{gm cm}^{-2}\ \text{sec}^{-1}$$

$$PV = nRT, \qquad V = \frac{nRT}{P}, \qquad n = \frac{F_m}{M}$$

$$R = 67.36 \text{ torr liter/mol degree}$$

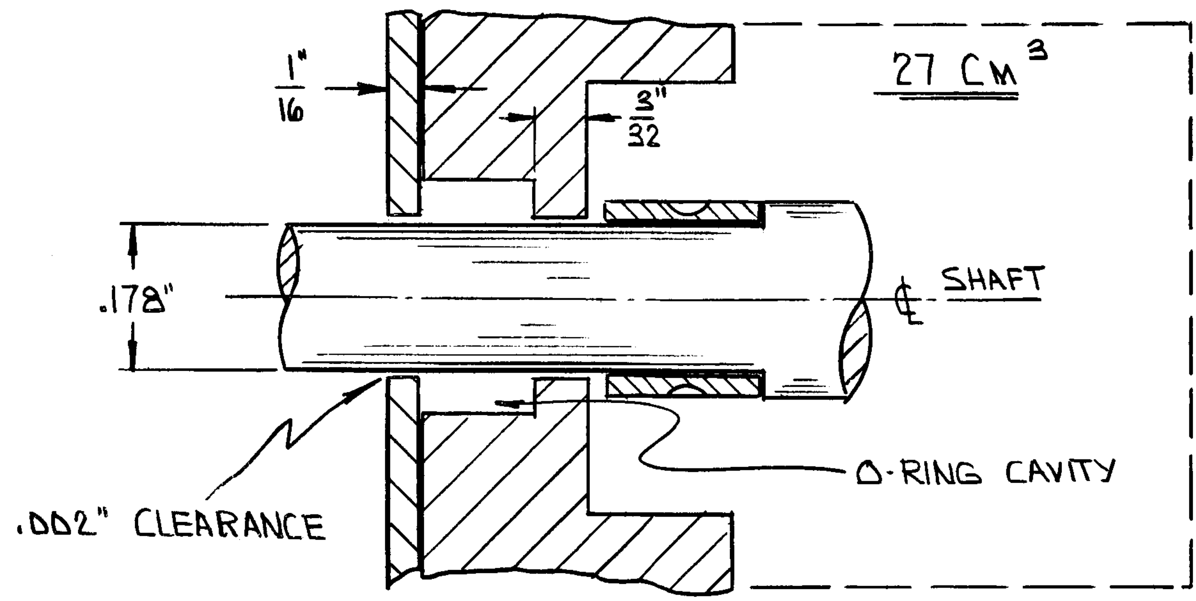


FIGURE 1B - CROSS SECTION - SHAFT SEAL

Volume Flux (orifice) $F_o = \frac{.0583\ P}{M} \sqrt{\frac{M}{T}}\ \frac{RT}{P}\ cm^2\ sec^{-1}$

$$= .0583 \times 62.36 \sqrt{\frac{T}{M}}\ cm^2\ sec^{-1}$$

$$= 3.638 \sqrt{\frac{T}{M}}\ cm^2\ sec^{-1}$$

For air at 25°C $\sqrt{\frac{T}{M}} = 3.207$

Therefore

$$F_o = 11.6\ 1/sec^{-1}\ cm^{-2} = 75.3\ 1/sec^{-1}\ in^{-2}$$

By considering the two annular passages of Fig. B1 as two orifices and two short tubes, the approximate formulae

$$\left(\frac{1}{F_t'} = \frac{1}{F_t} + \frac{1}{F_o}\right)$$

and

$$F_t = 401.6\ (A_i^2/H_i l_i)\ 1/sec^{-1}$$

given by Dushman on pages 102 and 103 can be used.

The meaning of the symbols is as follows:

F_o = Conductance of an orifice of any shape (1/sec)

A_i = Area of orifice (in^2)

F_t = Conductance of a long passage of any uniform shape (1/sec)

H_i = Perimeter of passage (in)

l_i = Length of passage (in)

F_t' = Conductance of assembly

69

Steady State

$$A_i = .002 \times \pi \times .178 = 1.12 \times 10^{-3}\ (in^2)$$

$$H_i = \pi \times .178 = 0.56$$

$$A_i^2/H_i = 2.23 \times 10^{-6}$$

Let F' = Conductance of assembly

Then

$$\frac{1}{F'} = \Sigma \frac{1}{F_i} = \frac{1}{F_1} + \frac{1}{F_2} + \frac{1}{F_3} + \frac{1}{F_4} \quad \text{sec/l}$$

$$F_1 = 75.3 \times 1.12 \times 10^{-3} = .842 \times 10^{-1}\ \text{l/sec} \quad \text{1st orifice}$$

$$F_2 = 75.3 \times 1.12 \times 10^{-3} = .842 \times 10^{-1}\ \text{l/sec} \quad \text{2nd orifice}$$

$$F_3 = 401.6 \times 2.23 \times 10^{-6}/(\tfrac{3}{32}) = 0.955 \times 10^{-2}\ \text{l/sec 1st passage}$$

$$F_4 = 401.6 \times 2.23 \times 10^{-6}/(\tfrac{1}{16}) = 1.435 \times 10^{-2}\ \text{l/sec 2nd passage}$$

$$\frac{1}{F'} = 1.19 \times 10^1 + 1.19 \times 10^1 + 1.05 \times 10^2 + 0.70 \times 10^2$$

(Note that the "resistances" of the passages exceed the "resistances" of the orifices considerably)

$$\frac{1}{F'} = 23.8 + 105 + 70 = 198.8\ \text{sec/liter}$$

$$F' = 5.0 \times 10^{-3}\ \text{l/sec} = 5.0\ \text{cm}^3\text{/sec}$$

Transient

Assuming all other conductances in the system are high in comparison and that there are no sources or sinks then

$$t = \frac{V}{F'} \ln \frac{P_1}{P_2}$$

$$= 2.303 \frac{V}{F'} \log \frac{P_1}{P_2}$$

Where

t = Time from P_1 to P_2 in seconds

V = System volume (cm^3)

F' = Conductance (or "pump speed") (cm^3/sec)

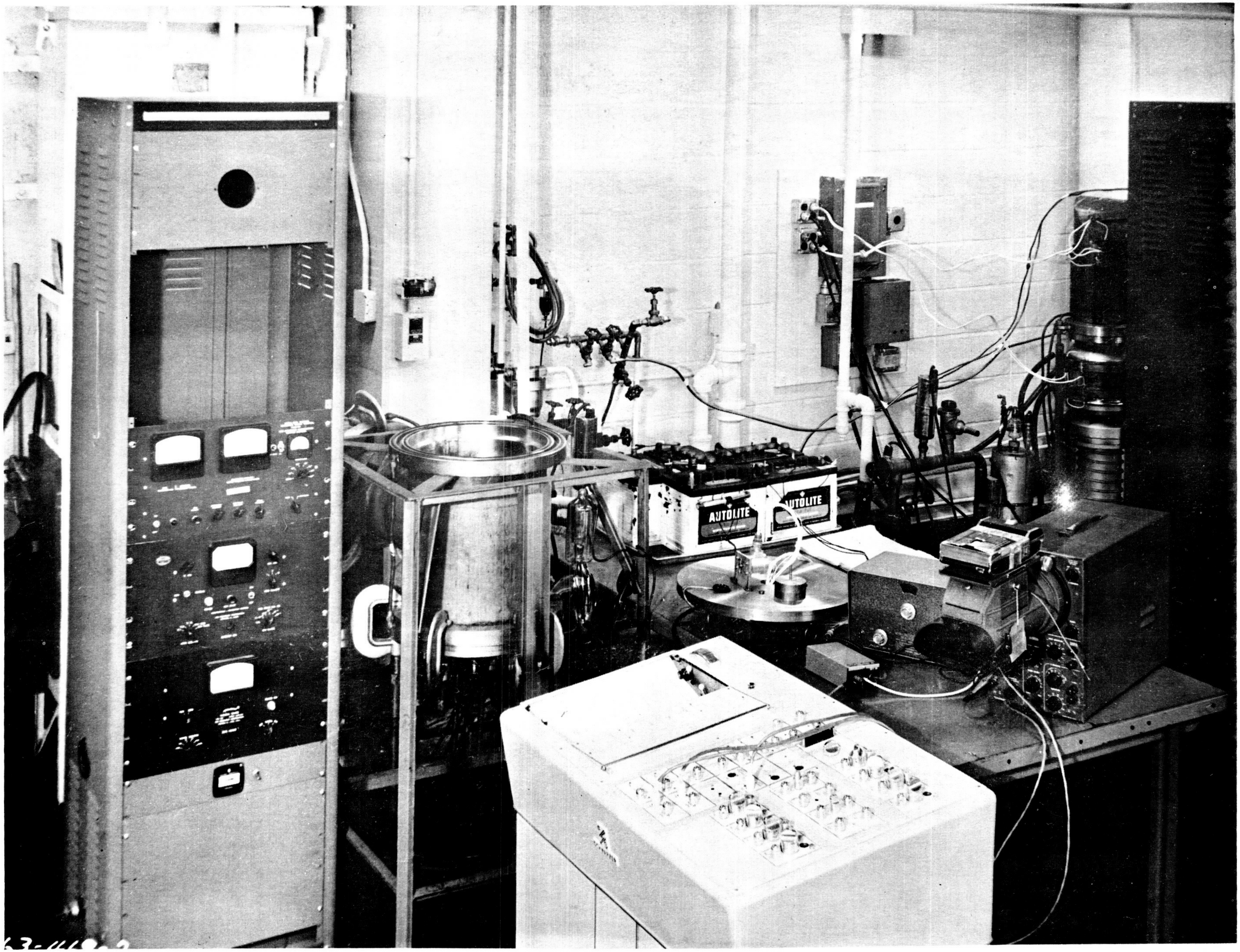
Since $V = 27$ and $F' = 5.0$, the time per decade pressure change is

$$\frac{2.303 \times 27}{5.0} = 12.4 \text{ seconds}$$

It is concluded that the volume (27 cm^3) of air initially present is of no consequence since it is attenuated one decade every 12.4 seconds and the unit was held in vacuum for one week before testing. The 12-second pumpdown rate per decade of pressure assumes zero outgassing from the inside walls of the cavity. The pressure in the vacuum chamber may have exceeded 10^{-8} momentarily shortly after the actuator was activated. However, it is worth pointing out that since the pumping speed was of the order of 750 l/sec whereas the conductance (F') of the actuator seal was only .005 l/sec the pressure in the actuator could have temporarily reached a value as high as 1.5×10^{-3} torr without raising the observed pressure in the vacuum system above 10^{-8} torr. Thus, temporary lubrication of the slip rings could have occurred. Other types of slip rings have been observed to be quiet at 10^{-3} torr but noisy at lower pressures.

Of the two jet actuators tested the closed one which communicated with the vacuum system only through the small annular channels described above, ran for 24 hours in vacuum at a low potentiometer noise level whereas the open one (end plate removed) ran quietly for only a few minutes. Possibly this reflects the presence of some residual high vapor pressure materials as well as of ordinary adsorbed gases inside of the actuators in spite of any cleaning operation which may have been used prior to receipt of the actuators. For example, if oil were present even after the eight-day vacuum exposure its rate of evaporation might have increased due to slight internal temperature increase when motion was started. Conceivably, then this lubricating reservoir might have been rapidly depleted in the open unit but remained for 24 hours in the closed unit with the oil vapor pressure kept high by the restricted path for escape. The pressure measurements would not reflect such behavior if the vapor involved were oil or other substance which would condense on some cold surface without entering the pressure gauge.

APPENDIX C



GENERAL VIEW OF TEST ARRANGEMENT SHOWING VACUUM SYSTEM AND CONTROLS, POWER SUPPLIES, MOUNTED SPECIMENS, OSCILLOSCOPE, AMPLIFIER, AND 8 CHANNEL RECORDER

FIGURE 1

74

MOUNTED ACTUATOR (NOTE STOPS), SEPARATE POTENTIOMETER, DETACHED BEARING AND LOAD ACCESSORY, PRIOR TO INSTALLATION IN CHAMBER

FIGURE 2

75

MOUNTED ACTUATOR, SEPARATE POTENTIOMETER, DETACHED BEARING AND LOAD ACCESSORY, PRIOR TO INSTALLATION IN CHAMBER

FIGURE 3

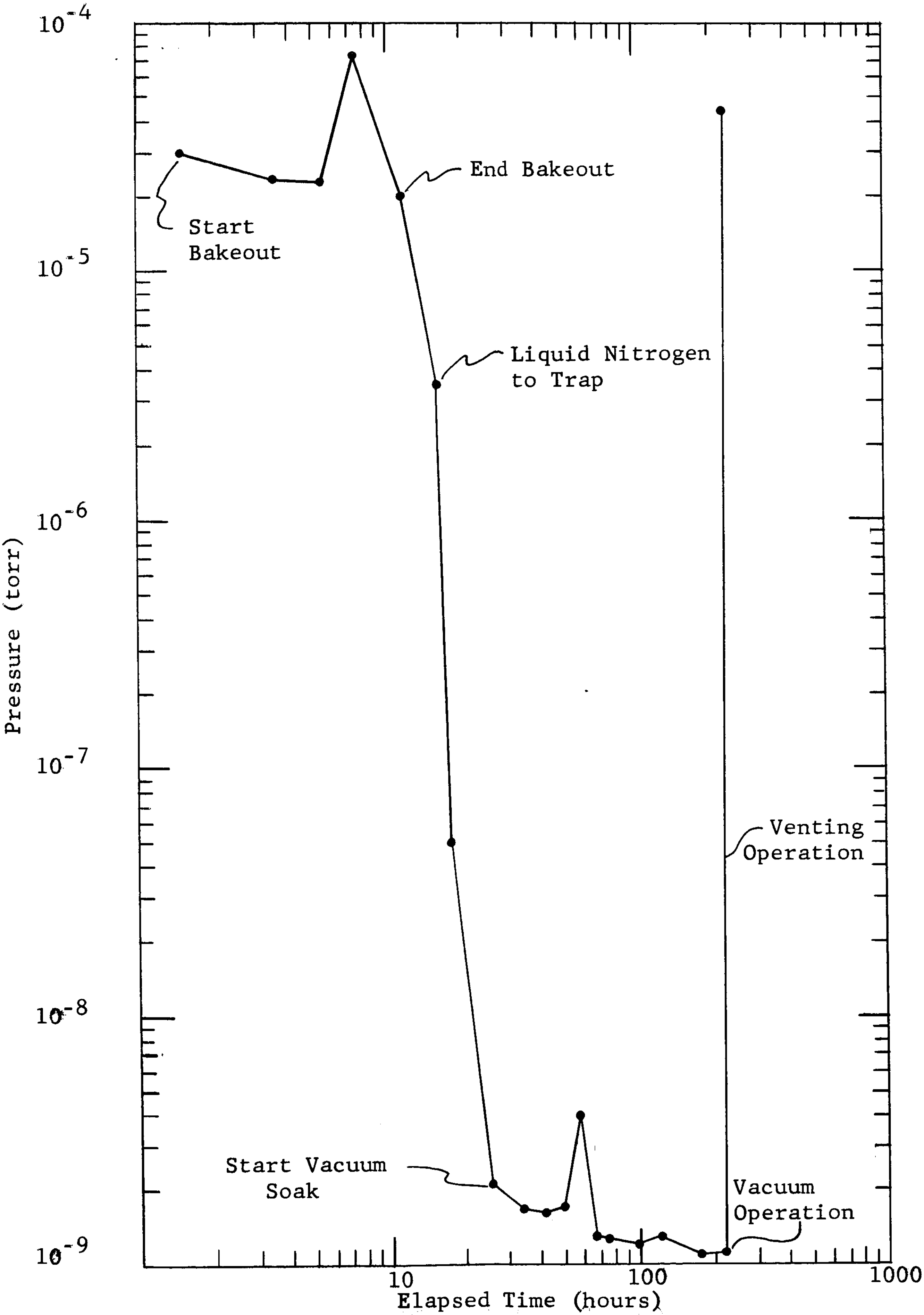


FIGURE 4

PUMPDOWN CURVE FOR VACUUM EXPOSURE NO. 1, JET VANE ACTUATOR, SERIAL NO. 01

77

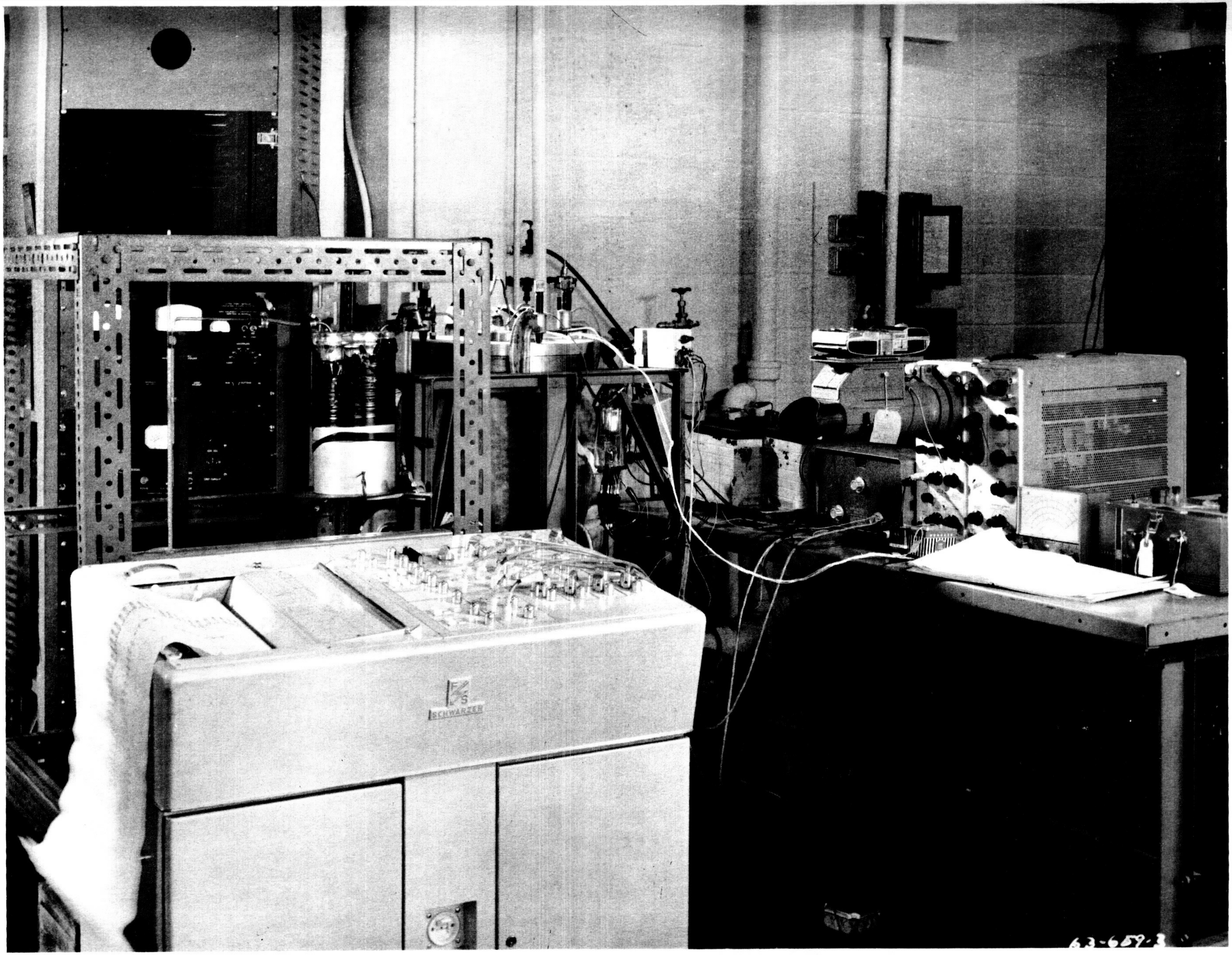
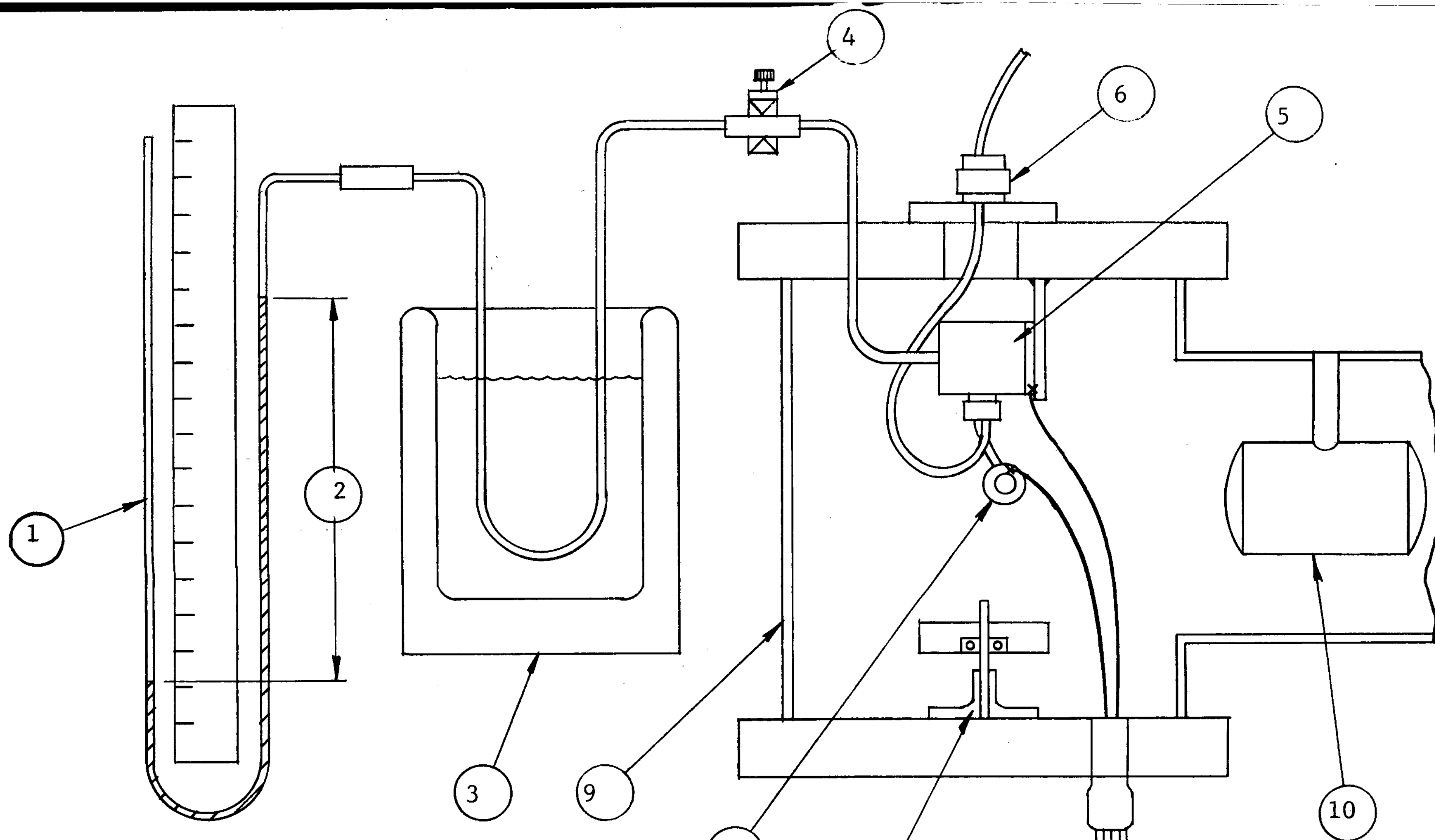


FIGURE 5

NRC ULTRAHIGH VACUUM SYSTEM NO. 142 AND
TEST SET-UP FOR JET VANE ACTUATOR EXPOSURE NO. 2

FIGURE 6

"U" TUBE MERCURY MANOMETER AND MERCURY VAPOR LIQUID NITROGEN TRAP USED TO MEASURE JET VANE ACTUATOR, SERIAL NO. 02, CASE PRESSURE DURING VACUUM EXPOSURE NO. 2



1. "U" Tube Mercury Manometer
2. Height of Mercury Indicating Case Pressure
3. Mercury Vapor Liquid Nitrogen Trap
4. Clamp -- Mercury Manometer
5. Jet Vane Actuator
6. Actuator Connection From Power Supply
7. Pre-Loaded Bearing Assembly
8. Static Potentiometer
9. NRC Ultrahigh Vacuum System No. 142
10. Liquid Nitrogen Trap in Pumping Manifold

FIGURE 7

SCHEMATIC OF TEST SET-UP FOR VACUUM EXPOSURE NO. 2
SHOWING CASE PRESSURE MEASURING SYSTEM AND BEARING PRE-LOAD SET-UP

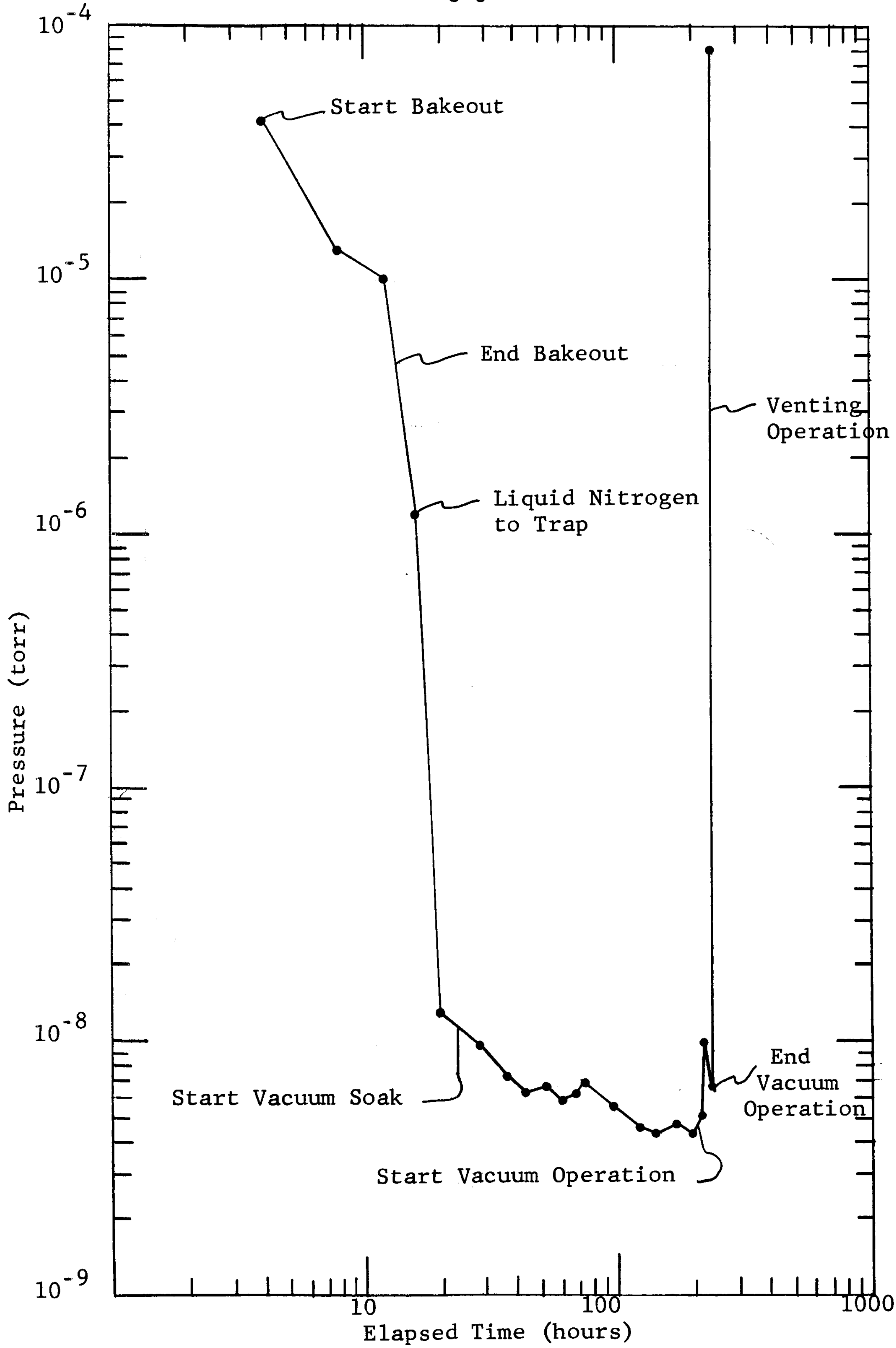
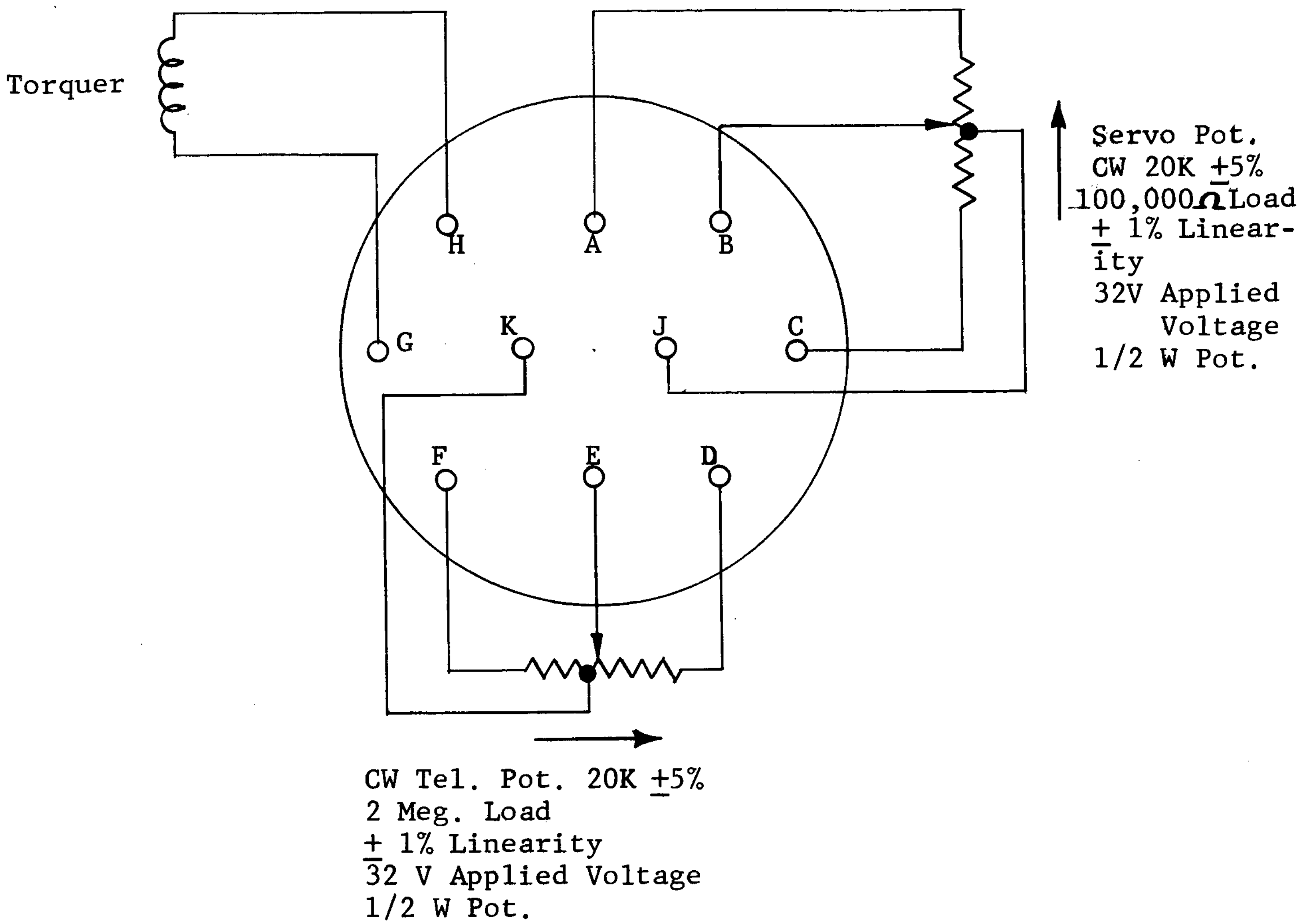


FIGURE 8
PUMPDOWN CURVE FOR VACUUM EXPOSURE NO. 2, JET VANE ACTUATOR, SERIAL NO. 02

81



Notes: 1. + Voltage on G CW Rotation Looking at Output Shaft of Torquer

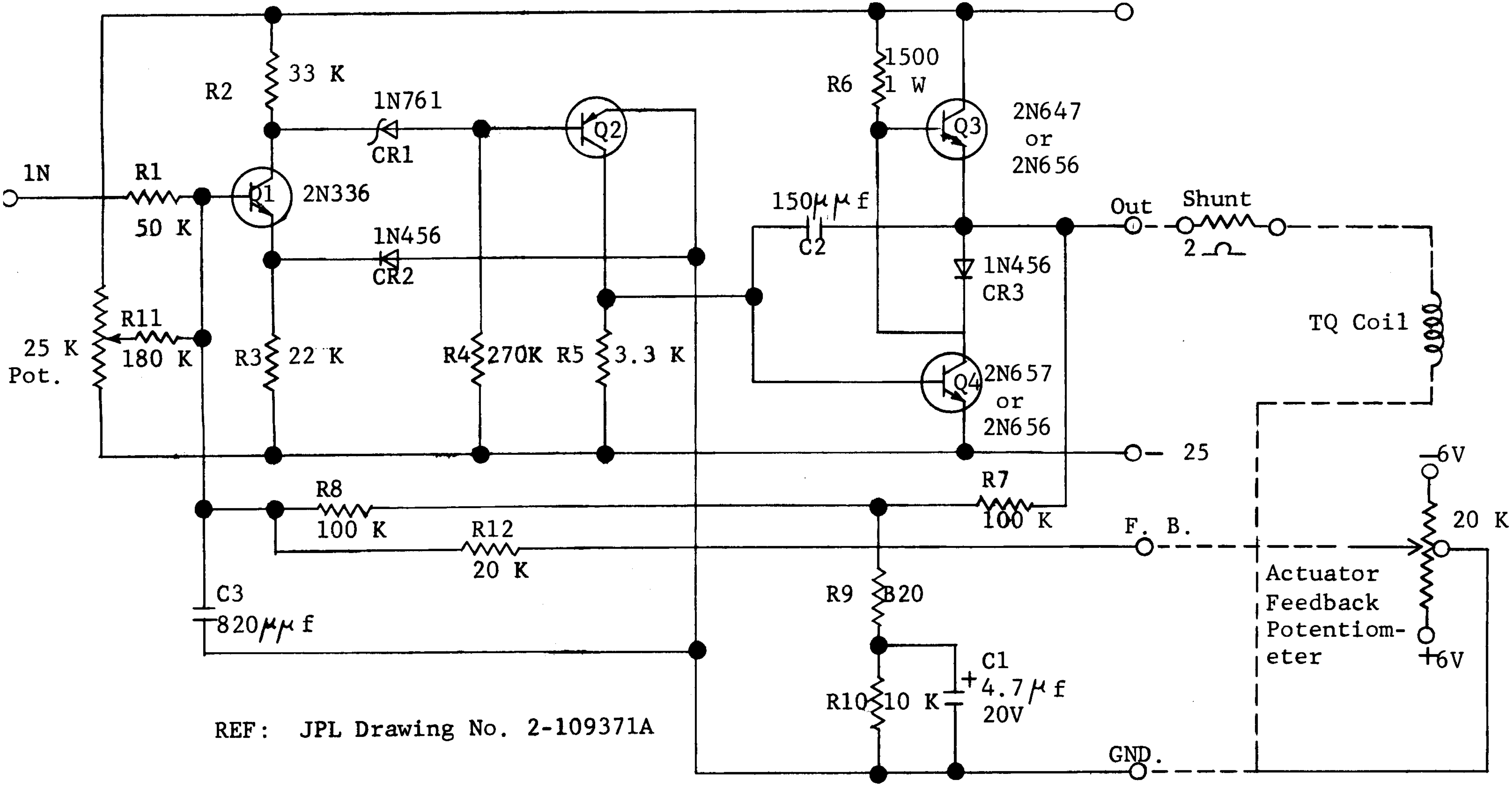
2. CW Rotation of Output Shaft Servo Pot. Slider Approaches Pin A

3. CW Rotation of Output Shaft Telemetering Pot. Slider Approaches Pin D

Ref: JPL Drawing 1-104208A

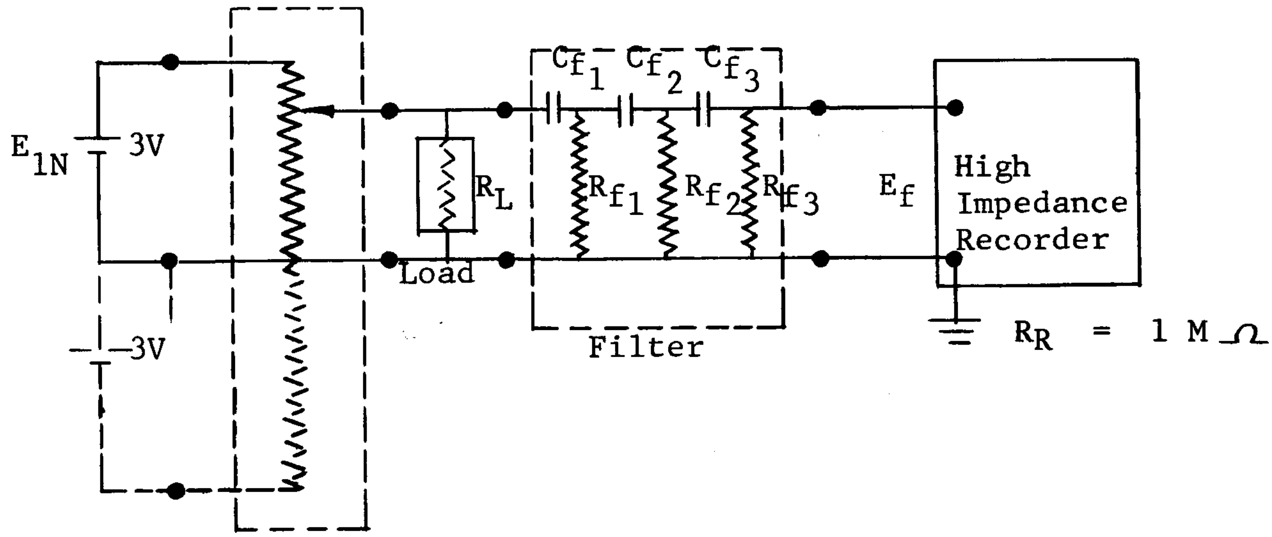
FIGURE 9

WIRING SCHEMATIC OF JET VANE ACTUATOR



REF: JPL Drawing No. 2-109371A

FIGURE 10
SCHEMATIC OF AMPLIFIER FOR
JET VANE ACTUATOR



SPECIFICATIONS FOR MARKITE "O" FILTER*

Markite No.	Time Constant Milli-seconds	R_{f_1} K	R_{f_2} K	R_{f_3} K	R_R K	C_{f_1} uf	C_{f_2} uf	C_{f_3} uf	Speed	θ_T
"O" Filter	2.46	820	820	820	2000	.003	.003	.003	60 rpm	2.25°

*REF: Test Report For Filtered Output -- Eng. Report P-429, page 4
Markite Corp., 155 Waverly Place, New York 14, New York

FIGURE 11

SCHEMATIC OF LOW FREQUENCY "O" FILTER

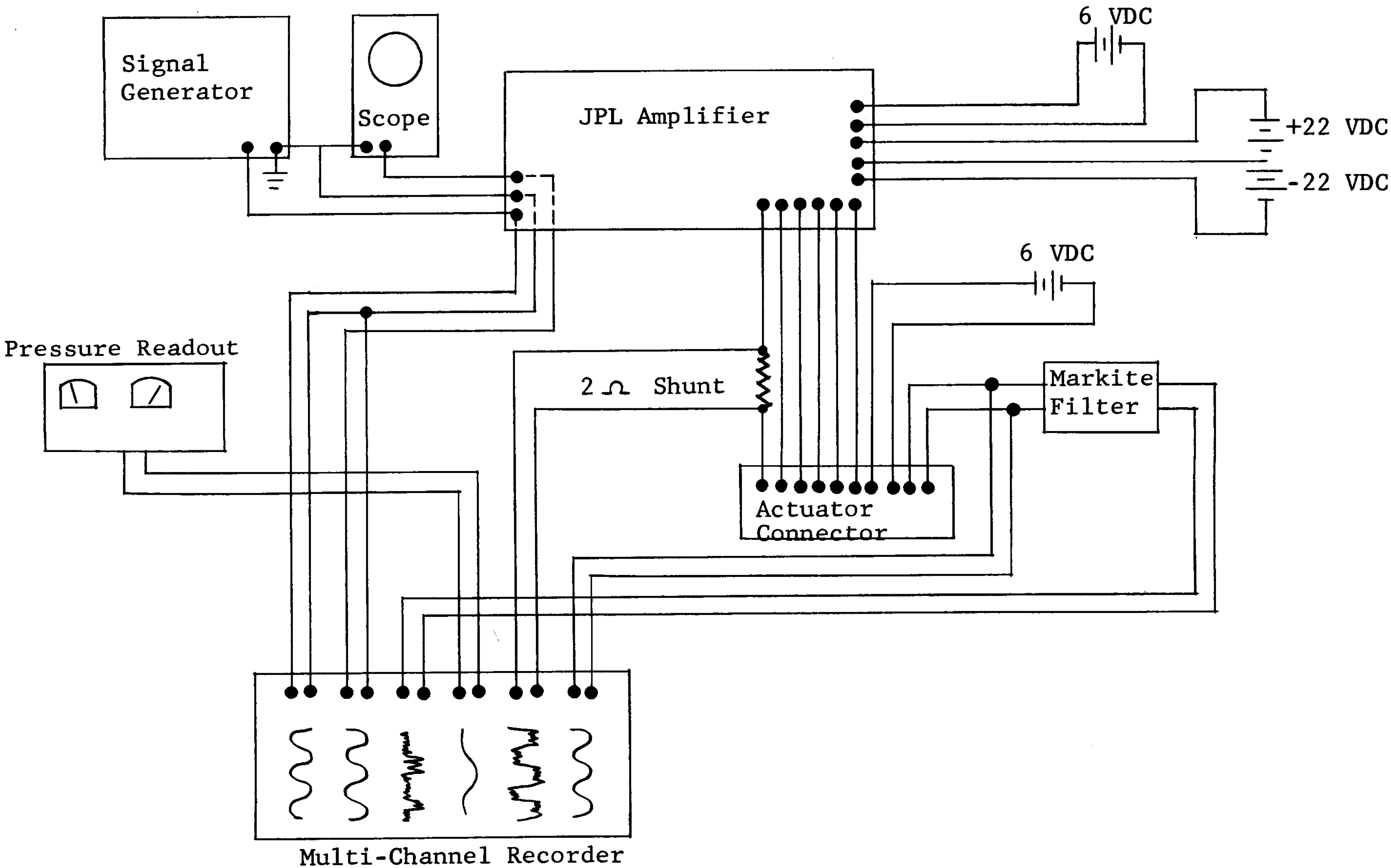
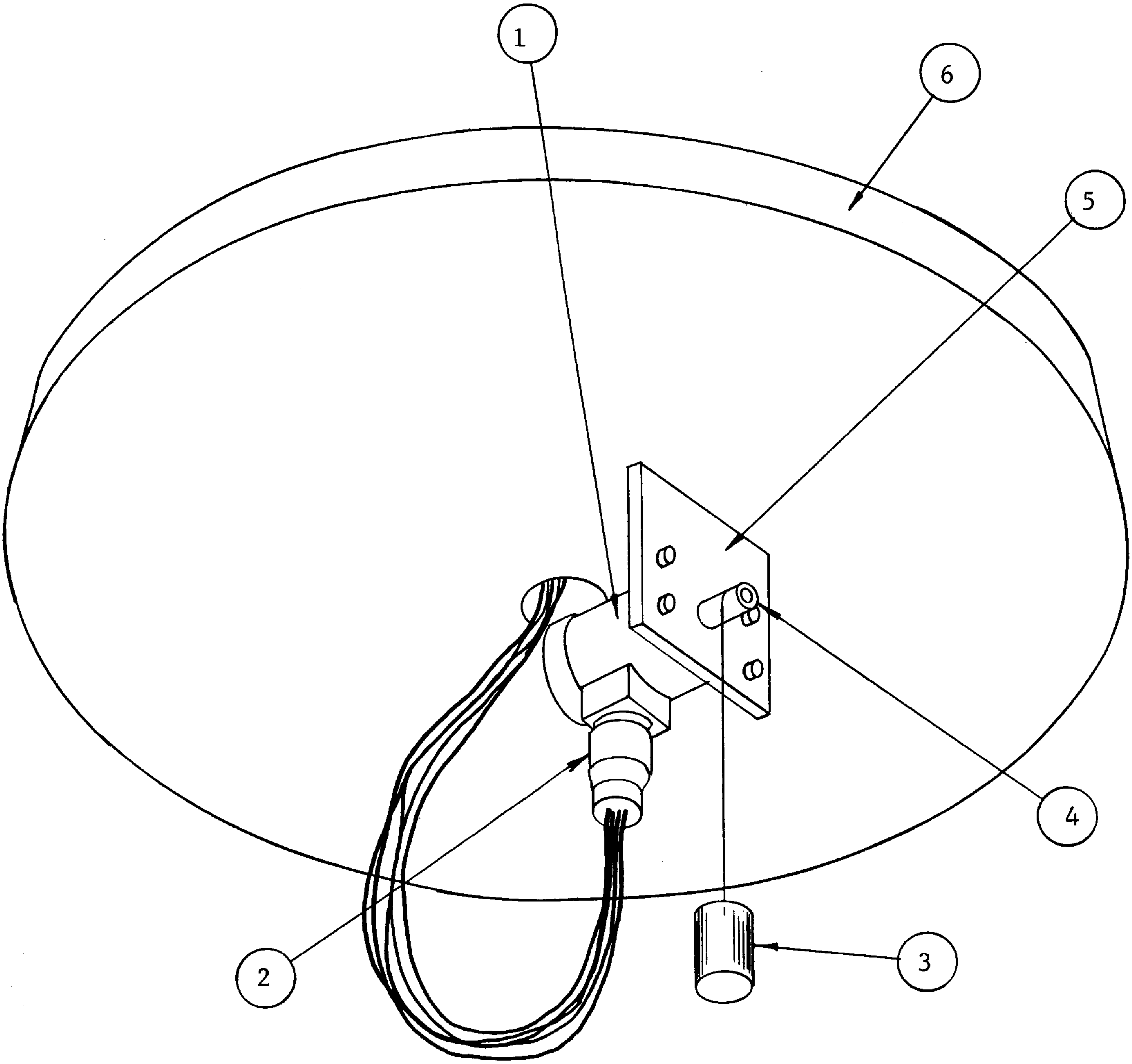


FIGURE 12

WIRING SCHEMATIC FOR INSTRUMENTATION AND POWER SUPPLY
FOR JET VANE ACTUATOR



1. Jet Vane Actuator
2. Jet Vane Actuator Plug
3. Dummy Weight
4. Pully (½" Dia.)
5. Mounting Plate
6. Vacuum Chamber Cover

FIGURE 13

CALIBRATION TEST SET-UP FOR

JET VANE ACTUATOR, TORQUE MOTOR

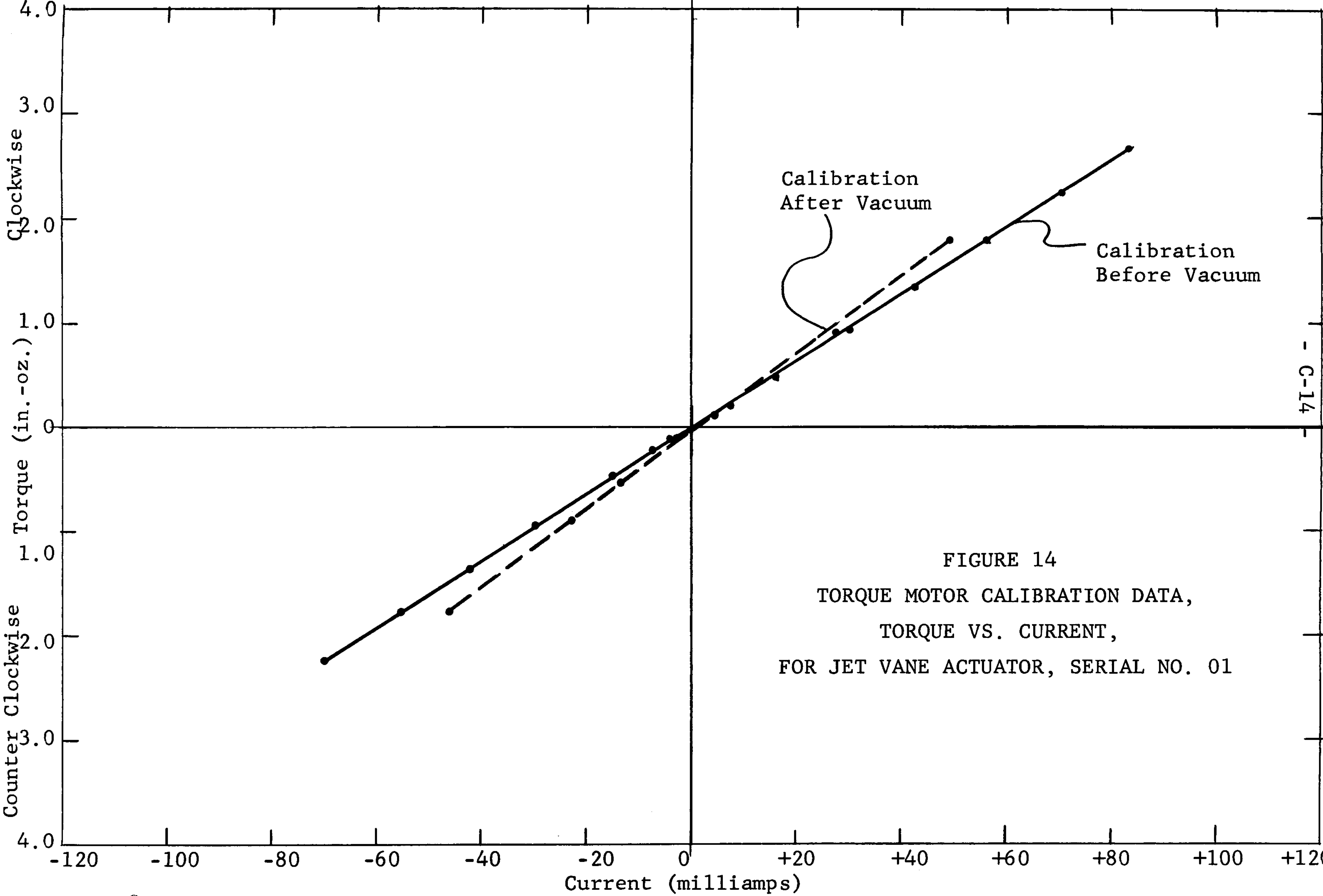


FIGURE 14
TORQUE MOTOR CALIBRATION DATA,
TORQUE VS. CURRENT,
FOR JET VANE ACTUATOR, SERIAL NO. 01

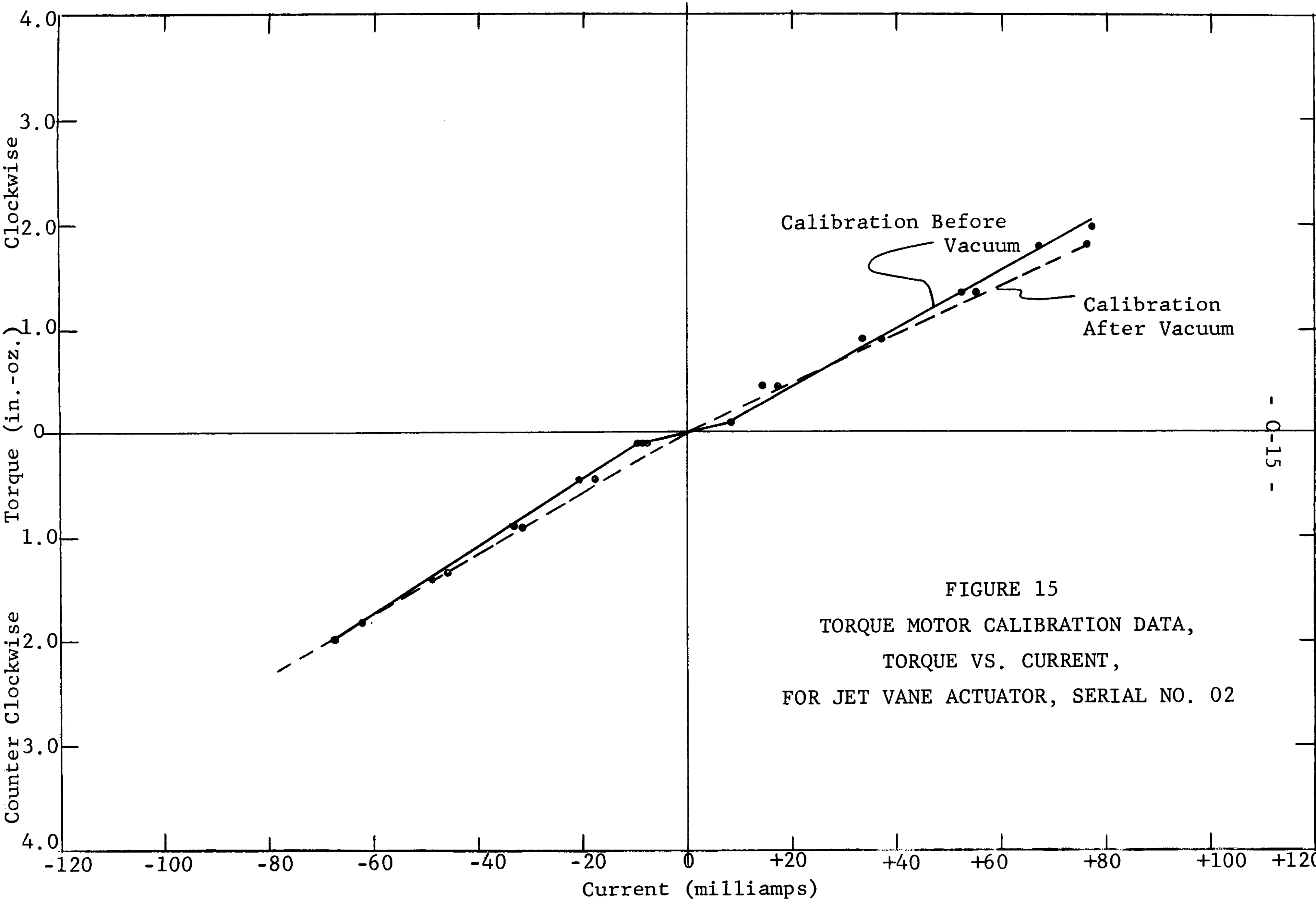


FIGURE 15

TORQUE MOTOR CALIBRATION DATA,

TORQUE VS. CURRENT,

FOR JET VANE ACTUATOR, SERIAL NO. 02

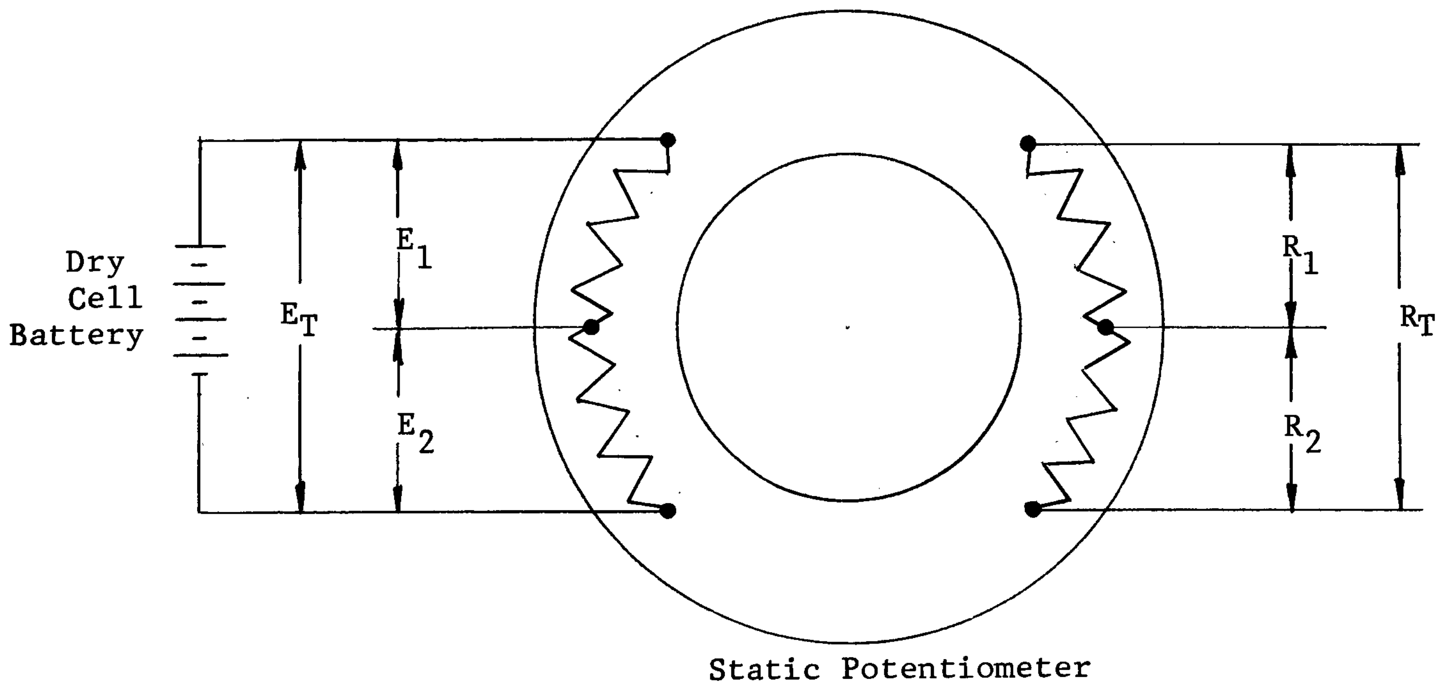


FIGURE 16

SCHEMATIC SHOWING RESISTANCE AND VOLTAGE DATA

TAKEN FOR STATIC POTENTIOMETER

APPENDIX D

TABLE 1

PRE-VACUUM ATMOSPHERIC TEST OF

JET VANE ACTUATOR, SERIAL NO. 1 WITH AMPLIFIER NO. 1

March 15, 1963, 2330 Hours

Elapsed Time (minutes)	Remarks	Input Voltage (volts)	Servo Potentiometer Voltage (volts)	System Pressure (torr)	Actuator Case Temperature (°F)	Torque Motor Current (milliamps)	Telemetry Potentiometer Noise (millivolts)
0	100 Cycle Noise Appeared on Both Torque Current and Telemetry Potentiometer Signals	±3.9	±1.4	760	78	±7.5	4.0
1.0		±3.9	±1.4	760	78	±7.5	4.0
2.0		±3.9	±1.5	760	78	±7.5	4.0
3.0		±3.9	±1.5	760	78	±7.5	5.0
4.0		±3.9	±1.5	760	78	±7.5	5.0
5.0		±3.9	±1.5	760	78	±7.5	5.0
6.0		±3.9	±1.5	760	78	±7.5	5.0
7.0		±3.9	±1.5	760	78	±7.5	5.0
8.0		±3.9	±1.5	760	78	±6.8	5.0
9.0		±3.9	±1.5	760	78	±7.5	5.0
10.0		±3.9	±1.5	760	78	±7.5	5.0
11.0		±3.9	±1.5	760	78	±7.5	5.0
11.7		±3.9	±1.5	760	78	±7.5	5.0

TABLE 2

LOG OF PUMPDOWN DATA AND POTENTIOMETER DATA

FOR EXPOSURE TEST NO. 1

(JET VANE ACTUATOR, SERIAL NO. 01, STATIC POTENTIOMETER, SERIAL NO. 100)
AND PRE-LOADED BEARING

Date/Time	Remarks	System Pressure (torr)	Temperature (°F) Act.	Pot.	Potentiometer Resistance (1000 ohms) M-N	M-P	N-P	Y-R	Y-Z	R-Z
3/15/63 1200	Read - after conditioning of potentiometer	760	76	76	19.5	10.5	10.5	19.5	10.5	10.5
2000	Read - after installation of potentiometer	760	76	76	19.0	10.1	10.3	19.0	10.5	10.5
2330	Torque and equipment calibrated									
3/16/63 0230	Mechanical Pump On	760	78	78						
0240	2" Diffusion pump on	3.0×10^{-2}	76	76						
0315	6" Diffusion pump on	1.0×10^{-4}	76	76						
0330	Bakeout started, liquid nitrogen to rear trap	6.0×10^{-5}	76	76						
0400	Read	3.0×10^{-5}	140	140						
0500	Read	2.5×10^{-5}	164	164						
0600	Read	2.4×10^{-5}	183	183						
0700	Read	1.8×10^{-5}	189	189						
0730	Read	1.8×10^{-5}	190	190						
0800	Read	2.3×10^{-5}	190	190						
0900	Read	2.0×10^{-5}	184	184						
1100	Read	5.0×10^{-5}	190	190						
1300	Read	3.0×10^{-5}	190	190						
1500	Bakeout ended	2.0×10^{-5}	189	189						
2010	Liquid nitrogen to front trap	2.0×10^{-5}	110	110						
2100	Read and Outgas	5.1×10^{-8}	70	70	19.0	10.3	10.6	18.9	10.5	10.2
3/17/63 0100	Read and Outgas	3.0×10^{-9}	65	65	19.0	10.2	10.5	18.9	11.0	10.2
0500	Read and Outgas	2.1×10^{-9}	58	58	19.0	10.5	11.0	19.0	11.0	10.5
0900	Read and Outgas	2.0×10^{-9}	49	49	19.0	10.5	11.0	19.0	11.0	10.[illegible]
1300	Read and Outgas	1.8×10^{-9}	47	47	19.0	10.5	11.0	19.0	11.0	10.[illegible]